GEOLOGY OF A PART OF NORTHWESTERN UINTA COUNTY, WYOMING

by

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ABSTRACT

The part of northwest Uinta County, Wyoming, covered by this investigation, contains both igneous and sedimentary rocks. The igneous rocks are tuffs of late Eocene age. These tuffs comprise the Fowkes and Bridger (?) formations (Veatch, 1907), and are the youngest formations exposed in the area.

Particular attention is paid to the Fowkes formation in an attempt to correlate it with the Norwood tuff of northeastern Utah.

Mapped strata range in age from Lower Cretaceous to late Eocene. A major unconformity in the section spans most of Upper Cretaceous time. A second unconformity represents the Paleocene-Eocene transition time.

Structural features include a major zone of normal faults, part of a broad syncline, a minor anticlinal fold, and landslide features. Most faults trend northerly, forming a parallel pattern.

Economic interests in the area center around oil, coal, clay, and highway construction materials. No economic production of oil is noted at the time of this writing (1961).

INTRODUCTION

Location and accessibility

The area described in this report is in the northwestern part of Uinta County, in the southwest corner of Wyoming. The area contains approximately 72 square miles, extending northward from the old site of Almy Station, Wyoming, to about the north boundary of Uinta County. It includes the region between the Wyoming - Utah boundary on the west and the west flank of the Bear River Divide on the east. It lies approximately four miles north of the town of Evanston, Wyoming, which is the only town in the immediate vicinity. (See Index Map, Plate 1.)

The area is accessible via Wyoming Highway 89 and several unimproved ranch roads. Highway 89 transects the southwestern corner of the area, extending from Evanston northwest to Woodruff, Utah. One unimproved road extends north along the east side of the Bear River valley for approximately 8 miles. A second unimproved road intersects Highway 89 at the point at which the highway crosses the Utah - Wyoming state line. It extends from this point northward, along the west side of Bear River valley, approximately 5 miles to the Heward Ranch.

Most of the area off the above described roads can be reached only on foot or horseback.

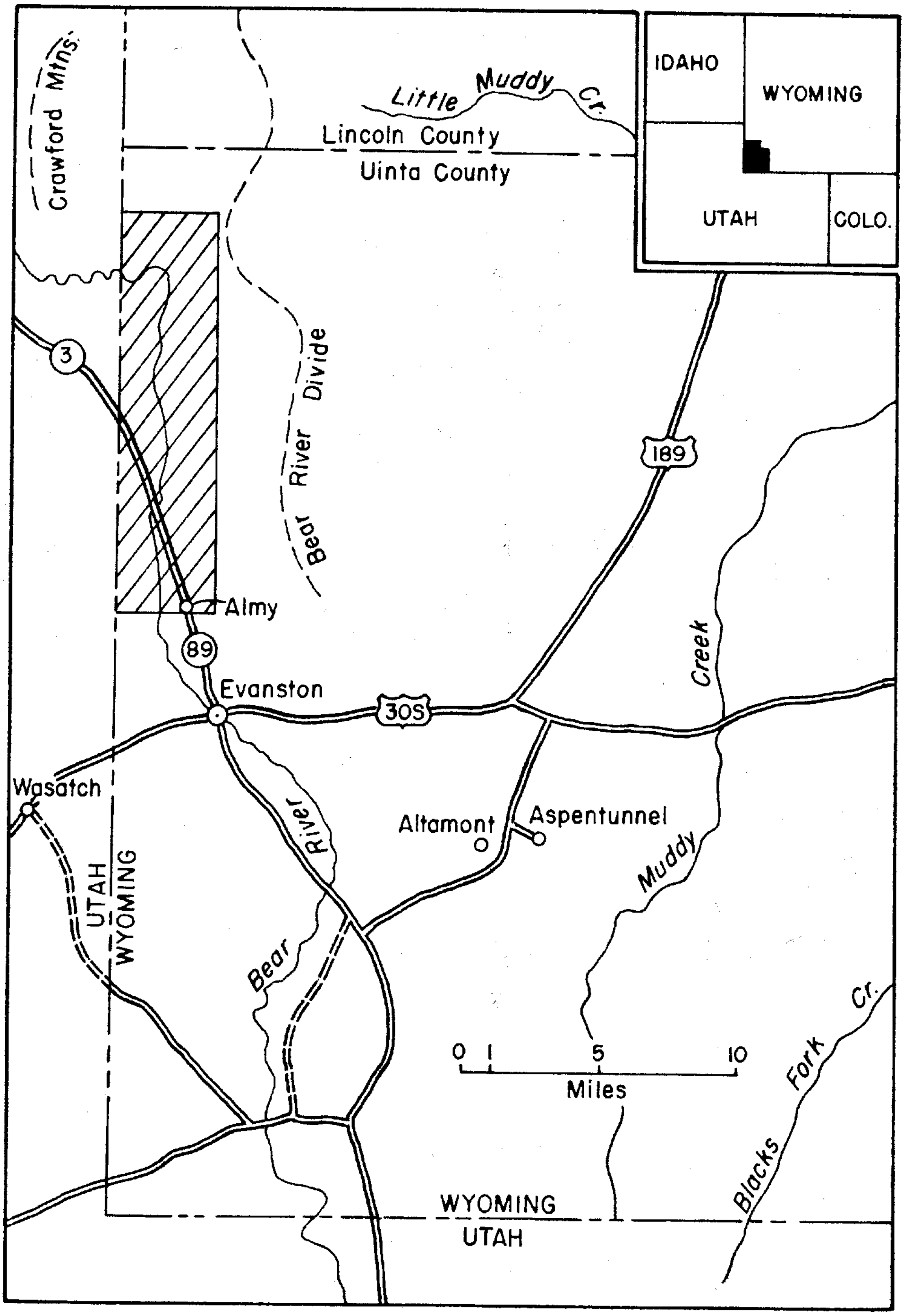

Plate 1. INDEX MAP

Showing the report area in northwestern Uinta County, Wyoming.

Purpose and scope

The purpose and scope of this report is fourfold:

1. The Fowkes formation was studied in detail to obtain a better understanding of its origin. An attempt has also been made to correlate the Fowkes formation with the Norwood formation of northeastern Utah.

2. In the light of the recent discovery by Tracy & Oriel (1959) that the Fowkes formation is stratigraphically higher than the Knight formation, rather than being between the Knight formation and Almy formation as described by Veatch (1907), a study has been made of the relationship between the Almy and Knight formations. A question has arisen as to the validity of the Almy formation (Eardley, 1959).

3. The upper portion of Veatch's Beckwith formation (1907) has been correlated with the Gannett group of southeastern Idaho (Burger, 1955). An attempt has been made to subdivide the upper Beckwith and to correlate such subdivisions with those of the Gannett group.

4. Detailed stratigraphic and structural data were collected in order to prepare a geologic map, measured stratigraphic sections, and structural cross-sections for the area.

Field work

Field work was conducted during the summer of 1960.

Base and geologic maps were prepared from aerial photographs procured from the U. S. Department of Agriculture, Commodity Stabilization Service, Performance Division. Contact prints were taken from project CVT, flight strip 1B, photos 143 through 155, and flight strip 2B, photos 14 through 26. Map scale was set at 1:21, 120 (3 inches = 1 mile). Horizontal control for photo assembly was taken from U. S. Department of the Interior, Grazing Service, Wyoming Map Number 33, prepared in April, 1944. Control was later adjusted to section corners found in the field.

The base map was constructed by use of radial-line templates and Kail Plotting Machine.

Elevation data are not available in the report area.

Stratigraphic sections were measured by the Brunton-tape method.

Geography

Topography and drainage. The area is one of medium relief (approximately 800 feet) and consists primarily of low, flat-topped hills and benches, bordering each side of the Bear River valley. Elevations range from 6,700 feet in the river valley to about 7,500 feet on top of the higher peaks.

Tributaries that drain the area to the Bear River become dry in late spring. The drainage pattern is dendritic.

Climate and vegetation. The climate is generally dry and cool. Winters are quite cold, with a fair amount of snow. Spring and fall seasons are of short duration and summers are relatively cool and dry.

Vegetation throughout the area consists chiefly of sagebrush and greasewood, with some small cedar trees growing in the higher elevations.

A very few large cottonwood trees are found locally near surface springs.

Land utilization. The land is utilized primarily for grazing of cattle and sheep. A very small amount of farming is conducted along the narrow river valley. Livestock feed is the principal produce.

Previous geologic work

Numerous scientific explorations of southwest Wyoming were conducted prior to 1900. Among the earliest of the explorers were Bonneville, Fremont, Clayton, Beckwith, Stansbury, and Englemann, during the years 1834 to 1858. These early investigations were concerned primarily with the study of the coal, oil, and paleontology of the region.

Federal Land Office surveys by Hayden (1869-1874) and King (40th parallel, 1876) included a general reconnaissance of southwest Wyoming. Clayburne and Durkee, of the Union Pacific Railroad, Meek, and Marsh conducted further studies in the area during the period 1872 to 1877.

Further investigations were conducted from 1879 to 1900 by Ward, White, Stanton, Ahern, Knight, and others.

Veatch (1907) published a comprehensive geologic and geographic report of southwest Wyoming. This work has served as the basic geologic reference in the area.

Mansfield (1927) made a major contribution to the geologic studies of adjacent areas in northeast Utah and southeast Idaho.

The University of Utah has sponsored a number of investigations of the geology of southwest Wyoming and adjacent parts of Utah. Dr. A. J. Eardley (1949, 1951, 1952, 1959) has published several works concerning the general region, and has directed several thesis studies in the area. Parts of southwest Wyoming and adjacent Utah have been included in unpublished theses of the University by Mount (1952), Randall (1952), Stark (1953), Wood (1953), Barrett (1953), Larsen (1954), Nixon (1955), Burger (1955), Madsen (1959), and others. Dr. W. L. Stokes and Dr. N. C. Williams have conducted important studies of adjacent areas in northeast Utah.

The U. S. Geological Survey began a program of detailed geologic investigation of southwest Wyoming in 1959. Results of this investigation are incomplete to date (1961), although a preliminary report has been published (Tracy and Oriel, 1959).

Regional geology

The geology of southwestern Wyoming is typified by broad folds, thrust faults of great magnitude, and thick sedimentary strata.

The area is situated slightly west of a major zone of folding and thrusting. It is characterized by continental sediments and extrusive igneous rocks, and normal faults.

The Bear River Divide on the east is a complexly folded and faulted sequence of Jurassic through Tertiary sediments, and is separated from the report area by a large normal fault, designated the Acocks Fault by Veatch (1907). Acocks Fault extends northward from the vicinity of Evanston, Wyoming, to the Salt Creek Basin, where it merges with the Medicine Butte Fault (Veatch, 1907). The Medicine Butte Fault borders the Bear

River Divide on the east. It is also a normal fault.

The crest of the Bear River Divide approximately marks the axis of the Rock Creek-Needles Anticline (Veatch, 1907). A broad syncline lies to the east of the Bear River Divide. This has been termed the Fossil Syncline, or Fossil Basin, (Veatch, 1907) and extends northward from an area approximately 10 miles east of Evanston, for about 75 miles.

A second syncline, Alkali Syncline (Veatch, 1907) lies slightly west of the Bear River Divide. The southern nose of the Alkali Syncline is included in the northern quarter of the report area.

A major thrust fault, the Absaroka thrust (Veatch, 1907), borders the east flank of Fossil Basin.

STRATIGRAPHY

General statement

Strata exposed in the area covered by this report range in age from Early Cretaceous to Recent. Several omissions in the stratigraphic record represent long periods of erosion or non-deposition, or both. Consolidated strata consist predominantly of sediments of fluvial and lacustrine origin. A thin sequence of Eocene volcanic derivatives occurs at the top of the consolidated section. Quaternary alluvium occupies the highest stratigraphic position.

The composite thickness of exposed rocks is approximately 4,000 to 4,500 feet. Formations mapped in the Evanston area may be correlated with much thicker sections to the east and north. Thick continental sequences in northeast Utah are of greatly different lithology than the Evanston section. The northeast Utah deposits are predominantly sandstone and conglomerate. The northwest Uinta County deposits consist of calcareous sandstones, limestones, shales, and minor amounts of conglomerate.

Consolidated rocks exposed in the area are divisible into six units suitable for mapping.

Cretaceous system

Gannett group. Mansfield (1927) named the Gannett group from exposures in the Gannett Hills of southeastern Idaho, and divided it into five members: Tygee sandstone, Draney limestone, Bechler conglomerate, Peterson limestone, and Ephraim conglomerate, from top to base.

The lowest exposed rocks north of Evanston were mapped as upper Gannett group, and efforts to subdivide them were unsuccessful. There are no stratigraphic breaks in the sequence. Similar lithology and stratigraphic position suggest a possible correlation between the Gannett exposures near Evanston and the Tygee and Draney members of the type Gannett. The Tygee and Draney members, in their type localities, are approximately 600 feet thick, whereas the part of the Gannett group exposed north of Evanston is only approximately 400 feet thick. No fossils were found in the Gannett group by the writer, which precludes definite correlation with members of the type Gannett group.

Burger (1955) correlated the units of the Beckwith formation (Veatch, 1907) with the Pruess, Stump, and Gannett formations of southeastern Idaho.

According to Burger (1955):

> "The Gannett sediments represent alternating periods of orogeny and quiescence in stony desert and fluvial environments."

The Jurassic-Cretaceous boundary is believed to lie within the Ephraim conglomerate member of the Gannett group (Cobban and Reeside, 1952; Burger, 1955; and Stokes, 1959).

Gannett exposures north of Evanston are overlain by black, carbonaceous, fossiliferous shales of the Bear River formation of Cenomanian age (see figure 1). The contact appears conformable.

The following section was measured approximately ½ mile south of the Upper Narrows, in section 5, T. 17 N., R. 120 W.:

Bear River formation Upper Gannett group	Feet
Sandstone, fine-grained, thick-bedded; brown to light brown, weathering dark brown to red-brown; slightly calcareous	1
Covered slope; yellow-brown to brown and gray clay float	1
Sandstone, fine-grained, massive; brown to yellow-brown; calcareous	1
Limestone, nodular; thin-bedded, weathers into plates; dark gray to black; contains a few, poorly preserved pelecypods	1
Limestone; massive crystalline; dark gray to black, weathers brown to yellow-brown	1
Covered slope	1
Limestone; massive crystalline; dark brown, weathers light brown to light gray	7
Covered slope; yellow-brown to brown clay float	10
Limestone; massive crystalline, thick-bedded, weathers into blocky, rectangular fragments; gray to gray-brown, weathers light brown to gray-brown	7
Covered slope; float contains small, angular fragments of gray to gray-brown, calcareous shale	7
Mudstone; slightly bentonitic; dark and light gray; weathers into small angular fragments	14
Mudstone; red and green-gray; weathers into small, angular chips; slope-former	2
Covered slope	10
Mudstone, silty; blue-gray to gray; slope-former	3

Limestone, fine-grained crystalline; brown, weathers yellow-brown; contains small, dark blue-gray limestone nodules, giving the appearance of pebble conglomerate	1
Covered slope	5
Limestone, fine-grained crystalline; nodular; brown, weathers light brown	1
Covered slope	5
Limestone; fine-grained crystalline; olive green	4
Covered slope; brown and yellow-brown clay float	1
Mudstone; green-gray and light brown; contains green and brown limy nodules	7
Limestone; massive crystalline; nodular; light green-gray; ledge-former	1
Covered slope	10
Limestone; massive crystalline; nodular; light green-gray; ledge-former	5
Covered slope	11
Limestone; massive crystalline; nodular; light green-gray; ledge-former	13
Sandstone, fine-grained; salt-and-pepper; thick-bedded; light gray; ledge-former	2
Covered slope	10
Sandstone, fine-grained; calcareous; gray to gray-brown; ledge-former	1
Claystone; dark and light gray; finely powdered; slope-former	9
Sandstone, calcareous; contains limy concretions; thick-bedded; light gray; ledge-former	3
Mudstone, calcareous, nodular; thin-bedded; red and gray; contains a thin limestone bed; crystalline; dark gray; approximately $\frac{1}{2}$ foot thick	6
Sandstone, calcareous; contains limy nodules; thick-bedded; light gray; ledge-former	1
Covered slope; red-brown to red-gray clay float	6

Shale, calcareous, carboniferous; dark gray to black, weathers light gray.................	1
Claystone; calcareous; red and gray; weathers into small, angular fragments, or chips...................................	2
Sandstone, calcareous; limy concretions; light gray; weathers into small, rounded fragments; ledge-former...................	6
Covered slope; red, gray, and green-gray claystone and mudstone float..................	22
Limestone; crystalline; nodular; light gray; weathers into small, rounded fragments; contains some interbedded blue-gray claystone..................................	14
Limestone; crystalline; nodular; light gray to gray-brown; weathers into blocky, angular fragments..........................	1
Covered slope; red and gray clay float..................	23
Limestone; crystalline; blue-gray nodules; dark gray, weathers light gray; thin, interbedded gray claystone.............	10
Limestone; sugary texture; sandy appearance; light gray to gray-brown..	9
Covered slope; red and gray clay float..................	12
Limestone; massive crystalline; concretionary; red-gray to gray; ledge-former......................................	23
Covered slope; red and gray clay float..................	15
Claystone; red and gray; interbedded limestone; crystalline; nodular; gray to gray-brown...............................	12
Sandstone; salt-and-pepper; gray; upper part thin-bedded; lower part massive; ledge-former......................................	15
Claystone; light red-brown; interbedded limestone; crystalline; gray.......................	13
Sandstone; dark gray to red-gray; interbedded thin conglomerate lenses; ledge-former...............................	10
Covered slope; red, gray, and purple float..............	20
Covered slope....................................	41
Total exposed Gannett group...........................	410

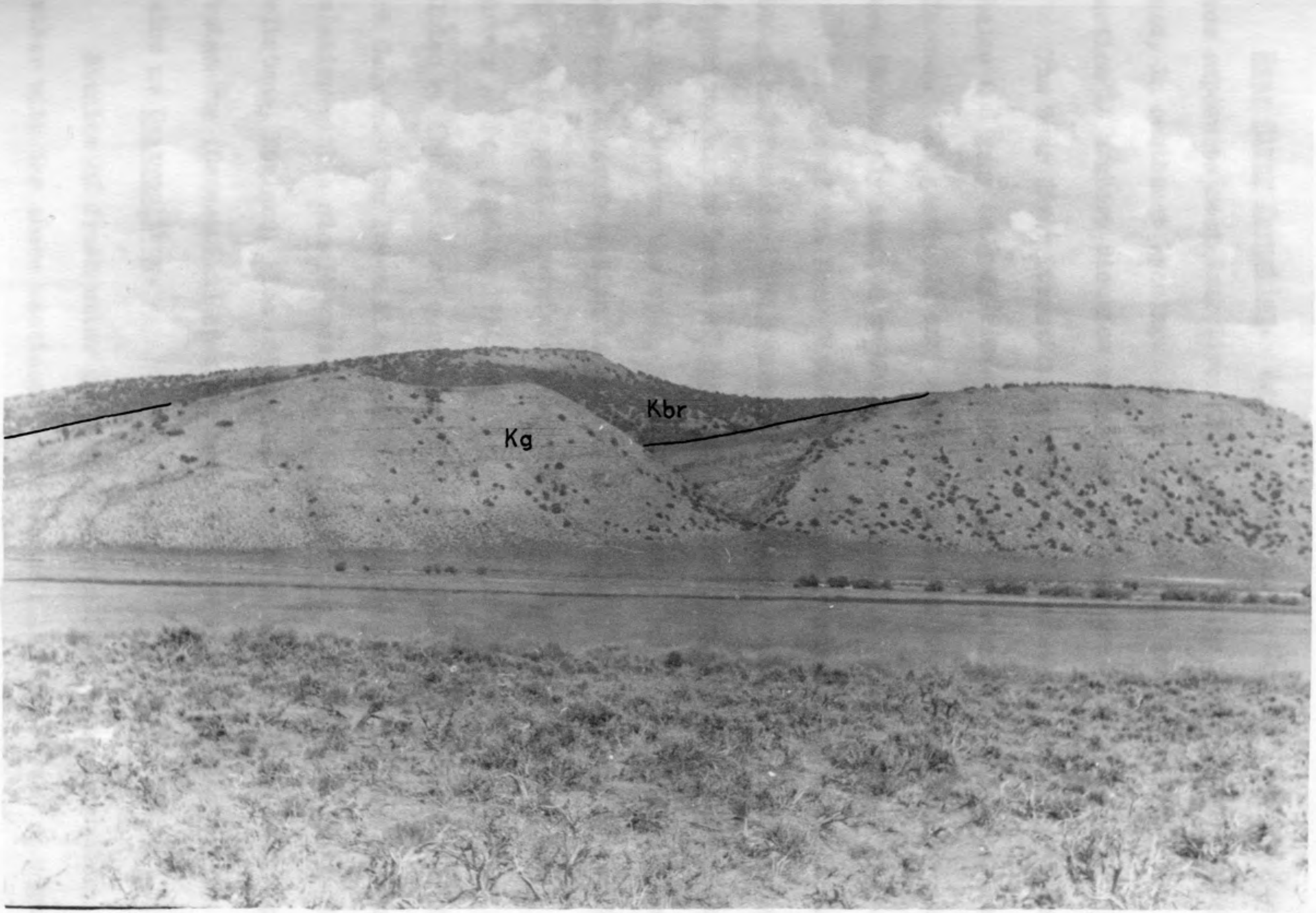

Figure 1. View eastward, just south of the Upper Narrows, showing Bear River formation overlying Gannett group.

Bear River formation. Hayden (1874) named the Bear River formation from exposures near Bear River City, on the Union Pacific Short Line Railroad, in southwest Wyoming. Bear River City no longer exists. The type section is a short distance southeast of Evanston.

The Bear River formation consists of interbedded black carbonaceous shales and gray to gray-brown crystalline limestones. It is very fossiliferous. The gastropod and pelecypod fauna of the Bear River strata has been thoroughly studied by White (1895) and Yen (1951, 1952a, 1954).

The age of the Bear River formation is a controversial subject. Cobban and Reeside (1951) correlate the Aspen shale with the Mowry shale of Montana on the basis of Gastroplites and Neogastroplites occurrences, assigning them to the upper Lower Cretaceous (Albian). The Aspen overlies the Bear River formation in southwest Wyoming. The correlation by Cobban and Reeside would therefore place the Bear River in the upper Lower Cretaceous. Yen (1952a, 1954) points out that the Aspen and Mowry are dated Albian on the basis of correlation with the Peace River formation of western Canada. The Peace River has been assigned to the Albian through correlation with a single species of Gastroplites found in the Gault clay at Folkstone, England. Yen notes that the Gault clay contains lower Upper Cretaceous (Cenomanian) species, and that the type Albian of France contains no Gastroplites.

Studies of fresh-water gastropods of the Bear River formation, together with the above mentioned observations, led Yen to the conclusion that the Bear River formation is of Cenomanian age.

Yen's evidence appears more convincing than that of Cobban and Reeside, and the writer here accepts the Cenomanian age for the Bear River formation.

Depositional environment of the Bear River strata appears to have been shallow, fresh to brackish water, in a sub-tropical climate.

Bear River deposits represent deep, local basin development during mid-Cretaceous time in southwest Wyoming. The formation has limited lateral extent: from Hilliard Flat, Wyoming on the south to southeast Idaho on the north, and from the Wyoming - Utah boundary on the west to Sneider Basin, Wyoming. Bear River strata attain a maximum thickness of 5,800 feet in central Uinta County (Burger, 1955). Approximately 750 feet of Bear River beds were measured by the writer, north of Evanston.

Fresh water mollusks and plant materials were collected from four Bear River exposures north of Evanston. Identifications were made by the writer.

Sampled localities:

1. Shell Hollow in section 3, T. 16 N., R. 120 W..
2. Approximately ½ mile south of Upper Narrows, at base of section, in section 4, T. 17 N., R. 120 W..
3. West-facing slope of Narrows Hill, in section 32, T. 18 N., R. 120 W..
4. Mouth of Lower Narrows, along road cut, in section 29, T. 18 N., R. 120 W..

Collections included:

Gastropoda:

Pyrgulifera humerosa (Meek)

Pyrgulifera stantoni White

Pyrgulifera sp.

Pachychiloides cleburni (White)

Pachychiloides sp.

Lioplacodes stachei inflatus Yen

Lioplacodes stachei (White)

Lioplacodes sp.

Campeloma sp.

Zaptychius haldemanni (White)

Physa sp.

Pelecypoda:

Corbicula durkeei (Meek)

Corbula pyriformis Meek

Corbula sp.

Unio belliplicatus Meek

Unio vestustus Meek

Unio sp.

Plant materials were fragmental and poorly preserved, and could not be identified by the writer.

The following section was measured approximately ¼ mile north of the entrance to the Upper Narrows, in section 32, T. 18 N., R. 120 W.:

Evanston formation
Bear River formation

	Feet
Covered slope; black soil, a few fresh-water gastropods in float	42
Limestone, crystalline; black to dark gray, weathers light gray; abundant fresh-water pelecypods, which weather to a chalk-white	11
Shale; black, carbonaceous; slope-former	51
Limestone, crystalline; black to dark gray; very fossiliferous, containing fresh-water pelecypods and gastropods, which weather white	4
Shale; black, carbonaceous; slope-former	22
Limestone, crystalline; black to dark gray; contains pelecypods and gastropods, which weather white	7
Shale; black, carbonaceous; slope-former	31
Shale; black, carbonaceous; contains small, angular fragments of purple, iron oxide stained limestone; slope-former	29
Limestone; crystalline; thin-bedded; black, weathers gray; very fossiliferous	20
Shale; black, carbonaceous; slope-former	10
Covered slope	10
Covered slope; float contains black, carbonaceous shale, and some fresh-water gastropods and pelecypods	133
Limestone; crystalline; thin-bedded; very fossiliferous; gray to gray-brown; weathers into rectangular, blocky fragments	11
Covered slope	22
Limestone; crystalline; thin-bedded; very fossiliferous; gray to gray-brown, weathers into blocky fragments	9
Shale; black, carbonaceous; slope-former	17
Limestone; crystalline; contains white, calcite lentils; dark gray to blue-gray, weathers gray-brown; slightly fossiliferous	5
Shale; black, carbonaceous; slope-former	5

Limestone; crystalline; contains white, calcite lentils; thin-bedded; fossiliferous; dark gray..........................	18
Shale; black, carbonaceous; slope-former..............	29
Limestone; crystalline; thin-bedded; very fossiliferous; gray-brown..................	5
Shale; black, carbonaceous; slope-former..............	80
Limestone; crystalline; thin-bedded; fossiliferous; black to dark gray................	3
Shale; black, carbonaceous; slope-former..............	9
Limestone; thin-bedded; fossiliferous; gray-brown..................................	2
Limestone, shaly; black, weathers gray; weathers into small, flat, splintery fragments................................	19
Limestone; gray-brown, weathers brown; very fossiliferous.............................	10
Covered slope..	14
Limestone; crystalline; very fossiliferous; dark brown to purple, weathers light brown to blue-gray; weathers into angular fragments..................................	16
Shale; carbonaceous; black to blue-black; weathers into fine, splintery fragments...........................	105
Total Bear River formation...........................	749

Unconformity. A major hiatus exists between the Bear River formation, of early Late Cretaceous age, and the overlying Evanston formation, of latest Cretaceous (Danian) and Paleocene age (see figure 2). This interval represents an absence of strata north of Evanston, which, to the east a few miles in central Uinta County, measures approximately 14,000 feet. Four formations have been mapped in this interval in adjacent areas to the east and north. Descriptions and thicknesses are taken from Veatch (1907), Burger (1955), and Nixon (1955).

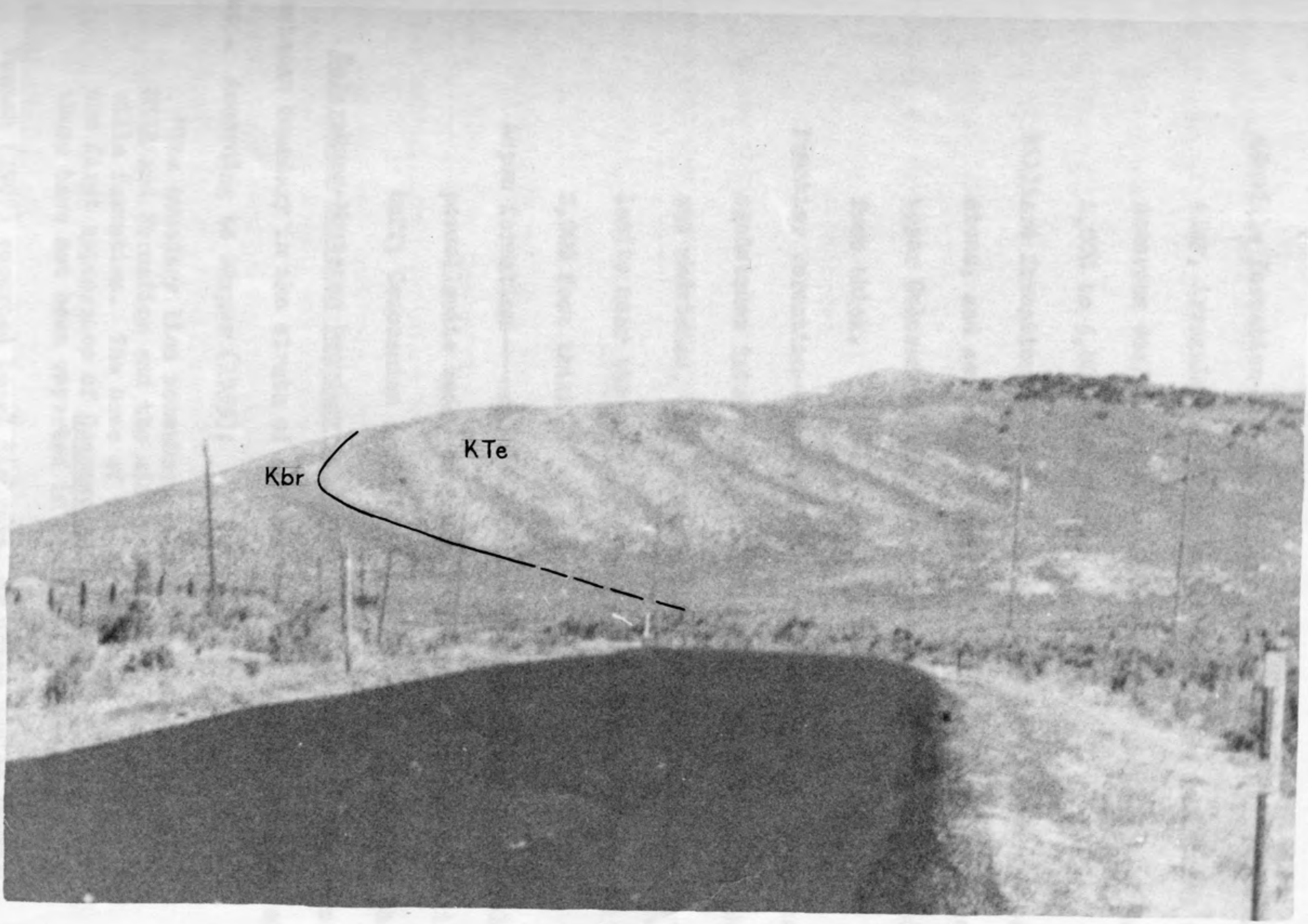

Figure 2. View northward from Wyoming Highway 89 at the southern boundary of the area, showing Evanston formation resting on Bear River beds.

Adaville formation-----yellow, gray, and black carbonaceous clay, irregularly bedded brown and yellow sandstone, with numerous coal beds; upper Montanan and lower Danian age; 4,000 to 5,000 feet thick.

Hilliard formation-----gray to black sandy shales, shaly sandstone, and several discontinuous white sandstone lenses; upper Coloradoan and lower Montanan age; 5,500 to 6,000 feet thick.

Frontier formation-----sandstones, siltstones, and conglomeratic sandstones interbedded with black, gray, and yellow shales and mudstones, with minor amounts of bentonite and porcellanite near the base; two main coal zones; Coloradoan age; 2,000 feet thick.

Aspen formation-----dark colored sandy shales and light colored porcellanite beds, composed chiefly of altered volcanic tuff; Cenomanian age (lower Coloradoan); 1,800 feet thick.

Coloradoan-Montanan boundary problem. The placement of the Coloradoan-Montanan boundary in the strata of southwestern Wyoming is a matter of dispute. According to Burger (1955):

> "The boundary lies somewhere between the middle of the Hilliard formation and the middle of the overlying Adaville formation. The base of the Montanan is placed at the first appearance of *Desmoscaphites bassleri*, but these have not been reported in southwestern Wyoming."

Veatch (1907) reported basal Niobrara, or upper Benton (upper Colorado) fossils in the Hilliard formation, 3,800 feet above the base.

He assigned the lower 3,900 feet of the Hilliard to the Coloradoan, and the upper 3,000 feet to the Montanan.

Cobban and Reeside (1952) found Niobrara fossils near the top of the Hilliard formation and in the lowest few hundred feet of the Adaville formation.

Gauger (1952) studied the microfossils of the Hilliard formation, and drew the following conclusion:

> "The lower 950(?) feet is Benton. The middle 350(?) feet is Niobrara. The upper 2,862 feet is definitely Montanan."

Since neither of the involved units are present in this area, the writer can make no additions to the boundary problem.

Tertiary system

Evanston formation. The Evanston formation was named by Veatch (1907) from exposures along the east side of the Bear River valley, about two miles north of Evanston, Wyoming.

Evanston beds consist of yellow, gray, and black claystone, siltstone, and shale, and brown and white sandstone and conglomerate, with abundant organic material. Discontinuous coal seams are characteristic of the formation. One coal bed is exposed for a short distance north of Evanston, but is absent in exposures north of Shell Hollow. The coal seams are dirty, low grade bituminous.

Abundance of clay and carbonaceous materials in the Evanston formation has resulted in slumping along outcrops. Individual beds are characteristically lenticular and discontinuous. No beds were continuous enough to serve as reference horizons.

Evanston exposures have been mapped throughout the Fossil Basin. Outside this area, the Evanston formation is not represented. Evanston strata represent a local basin of deposition, of moderate depth.

Burger (1955) suggests that the Evanston formation may be equivalent to the upper portion of the North Horn formation, the lower portion of the Flagstaff formation, and possibly the Currant Creek formation of the western Uinta Mountains, Utah.

The Evanston formation rests unconformably upon the Bear River formation north of Evanston, Wyoming. In the Sage and Kemmerer, Wyoming, area the Evanston rests unconformably upon the Adaville and older formations (Tracy and Oriel, 1959).

A problem exists regarding the age of the Evanston formation. According to Tracy and Oriel (1959):

> "Vertebrate remains found by the writer 265 feet above the base of the unit in the section along the southern boundary of the Kemmerer Quadrangle include a part of the jaw of a Triceratops cf. T. flabellatus Marsh, indicating probably Lance, or latest Cretaceous, age (G. E. Lewis, written communication, 1958). A vertebrate fauna found by C. L. Gazin 250 to 300 feet below the top of the unit in the northwest corner of Sec. 14, T. 21 N., R. 117 W., includes Plesiadapis cf. P. fodinatus Jepsen,

> Phenacodus sp., and other genera indicative of Tiffanian or early late Paleocene age (Gazin, 1956a, p. 708). Plant remains from the top and bottom of the formation are in accord with these determinations (R. W. Brown, written communication, 1955, 1958) and indicate that the Cretaceous-Paleocene boundary may lie within the upper finer-grained part of the formation."

Micropaleontological studies of the Evanston formation led Barrett (1953) to the conclusion that the Evanston is entirely Paleocene. Barrett further concludes that the Cretaceous-Tertiary boundary is included in the major hiatus between the Evanston and Bear River formations. These conclusions are not in accord with those of Tracy and Oriel (1959).

This writer measured 1,330 feet of Evanston strata near Shell Hollow. Barrett measured 732 feet of Evanston approximately one-half mile south of this writer's measured section. Barrett indicated a small part of the basal Evanston strata was unexposed. The additional strata assigned to the Evanston by the writer were mapped as Bear River formation by Barrett. There is doubt about the exact position of the contact, due to alluvial cover.

The lower 315 feet of the writer's measured Evanston formation may actually be Bear River strata. These beds are limestones, light gray to brown and red-brown, massive to sugary textured. No fossils were found in these limestones. The beds in question contrast with the upper limestones of the known Bear River formation in color, texture, and fossil content. No break is found between the base of the beds in question and the top of the known Evanston formation. Sedimentation appears to have been continuous throughout the sequence.

The above features have led the writer to arbitrarily place the Bear River - Evanston contact below the limestones in question.

The writer's measured thickness of the Evanston formation (1,330 feet) is in close agreement with those reported by Veatch (absent to 1,600 feet) and Tracy and Oriel (1,200 feet).

In view of the above evidence, the writer is inclined to agree with the proposal that the Cretaceous-Tertiary boundary lies within the Evanston formation, probably below the section covered in Barrett's study. This relationship, however, is conjectural due to lack of accurate dating of the lower portion of the Evanston in this vicinity.

The Evanston formation rests unconformably on the Bear River formation in the vicinity of Shell Hollow. Variations in strike range from 30 to 45 degrees between the two formations. Dips vary as much as 15 degrees. The lithologies of the two formations in this area are very dissimilar. Bear River lithology is easily recognized, consisting of dark gray to black, carbonaceous, highly fossiliferous shales and limestones. The overlying Evanston strata are composed of light gray to white, brown, and yellow sandstones, calcareous sandstones, and limestones, interbedded with vari-colored clays.

Barrett (1953) describes the depositional environment of the Evanston as being a moist and cool climate, with abundant fresh-water streams and ponds.

The Evanston formation is unconformably overlain by the Wasatch formation in the report area (see figure 3).

Plant remains are abundant in the Evanston formation, but specimens collected were too poorly preserved to be identified by the writer.

The following section was measured about ½ mile east of the junction of Wyoming Highway 89 and the unimproved road traversing the east side of the Bear River valley north of Almy Station, in section 11, T. 16 N., R. 120 W.:

<u>Wasatch formation</u>
Evanston formation

	Feet
Covered slope; yellow-brown, pink, and gray claystone float..............................	75
Siltstone; thin-bedded; light gray, with prominent iron stains; weathers into sharp, angular fragments......................................	3
Claystone, shaly; thin lenses of light gray sandstone; slightly carbonaceous; dark gray to gray-brown, weathers light gray; slope former................................	29
Siltstone; thin-bedded; dark brown to red-brown, weathers purple, maroon, to rust color, with pronounced iron oxide stains; weathers into small, angular fragments......................................	3

Sandstone, medium grained; thin-bedded to platy; slight cross-bedding; fossil plant material; brown to yellow-brown, salt-and-pepper appearance...........................	11
Siltstone; slightly carbonaceous; dark gray to maroon; slope-former..	37
Sandstone; fine-grained; thin-bedded; yellow-orange, weathers maroon to rust..........................	4
Coal; high proportion of silt and clay (very dirty); contains thin, yellow mineralized bands (appearance of some uranium mineral); slope-former..........................	29
Sandstone, silty; fine-grained; thin-bedded; dark brown and red-brown to yellow-brown; weathers a deep rust to maroon color............................	3
Sandstone, silty; fine-grained; thin-bedded to platy; light gray to light brown....................................	3
Claystone, silty; slightly carbonaceous; dark gray, weathers light gray; slope-former......................	5
Siltstone; very dark gray-brown; iron stained surfaces, dark rust to maroon and purple......................	2
Claystone and siltstone; dark gray; weathers light gray; slope-former...............	35
Sandstone; fine-grained; thick-bedded; yellow-brown; weathers orange-rust to maroon and purple......................	4
Claystone and siltstone; dark gray, weathers light gray; slope-former...............	28
Shale, silty; thin-bedded; black, weathers blue-gray................................	3
Coal, shaly, silty (poor grade); forms black and gray mottled slope..............	28
Sandstone; fine-grained; thin-bedded; weathers into large, angular fragments; dark rust-red to maroon, weathers maroon to purple, highly stained with iron oxide.........................	2

Claystone; gray-brown; weathers light gray to white; slope-former..........................	28
Sandstone; fine-grained; thin-bedded; weathers into large, angular fragments; dark rust-red to maroon, weathers maroon to purple, highly stained with iron oxide..............	4
Claystone; dark gray, weathers light gray to white; slope-former......................	38
Covered slope...	82
Sandstone; very fine-grained, massive; thin-bedded; calcareous; light gray..............	1
Covered slope...	1
Sandstone; very fine-grained, massive; thin-bedded; calcareous; light gray..............	6
Covered slope...	20
Conglomerate; thin-bedded; quartzite and chert pebbles ½ inch to 1 inch in diameter, slightly rounded to sub-angular; poorly cemented; gray-brown to yellow-brown, with iron oxide stains..................................	17
Sandstone; medium-grained, massive; thick-bedded; light gray to white, with prominent yellow to yellow-green iron oxide stains..........................	8
Sandstone; coarse-grained; laminated; pink to brown......................................	2
Covered slope...	3
Conglomerate; thin-bedded; quartzite pebbles 1 inch to 3 inches in diameter, slightly rounded; poorly cemented; brown to red-brown..	10
Claystone; gray; slope-former..........................	23
Conglomerate; thin-bedded; quartzite pebbles ¼ inch to 1 inch in diameter; dark brown, with iron oxide stains..	13
Sandstone; fine-grained; light gray to white, with iron oxide stains; slope-former..	5
Sandstone; coarse-grained; slightly conglomeratic; yellow-brown to red-brown; slope-former..........................	14

Covered slope; sandstone and claystone float	30
Claystone and sandstone; light gray to white; slope-former	53
Covered slope	89
Quaternary alluvium	119
Covered slope	11
Sandstone; fine-grained; thin-bedded; yellow-brown to gray-brown, with bands of iron oxide stains; salt-and-pepper appearance	5
Sandstone; fine-grained; sugary textured; thick-bedded; light gray, with yellow bands; becomes more yellow to yellow-brown, with light gray bands, near the top	16
Sandstone; fine-grained; thick-bedded; sugary texture; light gray to white	5
Sandstone; medium-grained; thin-bedded; gray, salt-and-pepper appearance, weathers yellow-brown, with gray and yellow-brown bands	2
Claystone, sandy; gray; slope-former	3
Sandstone; medium-grained; thin-bedded; light brown to yellow-brown	2
Covered slope	22
Sandstone; fine-grained; thin-bedded; light gray to white	14
Covered slope	19
Sandstone; fine-grained; thin-bedded; light brown with dark brown bands	3
Sandstone; fine-grained; thin-bedded; slightly calcareous; light gray, with iron oxide stains	10
Sandstone; medium-grained; thin-bedded; gray-brown	33
Sandstone; fine-grained; thin-bedded; calcareous, with calcite bands; brown to gray-brown	7
Limestone, sandy; crystalline, massive; thin-bedded; brown to red-brown; weathers into large, rounded fragments	17
Limestone; sugary texture; thin-bedded; light gray, with iron oxide stains	43
Limestone; crystalline; brown; fractures into conchoidal, rounded fragments	2

Limestone; crystalline; thin-bedded; dark gray, weathers light gray..................	51
Limestone, shaly; sugary texture; light gray....................................	8
Limestone; sugary texture; thin-bedded; gray to light gray......................	18
Limestone, shaly; granular; gray....................	17
Covered slope....................................	152
Total Evanston formation...........................	1,330

<u>Wasatch formation</u>. Hayden (1869) first suggested the name "Wasatch group" for the sequence of coarse clastics, of Eocene age, in the southwestern Wyoming - northeastern Utah region. His type locality was not clearly defined, including the area from Evanston, Wyoming westward into Echo Canyon, Utah. The name is thought to have been derived from Wasatch Station, southwest of Evanston, Wyoming.

Veatch (1907) subdivided the group into three members:

Almy formation-----named from the coarse, conglomerate exposures east of the old town of Almy, Wyoming. The Almy formation constituted the basal member of the group.

Fowkes formation-----named from the light gray to white tuffaceous and fresh water limestone deposits near Fowkes ranch, north of Evanston. This unit represents a reworked deposit of volcanic ash.

Knight formation-----named from exposures of red, pink,

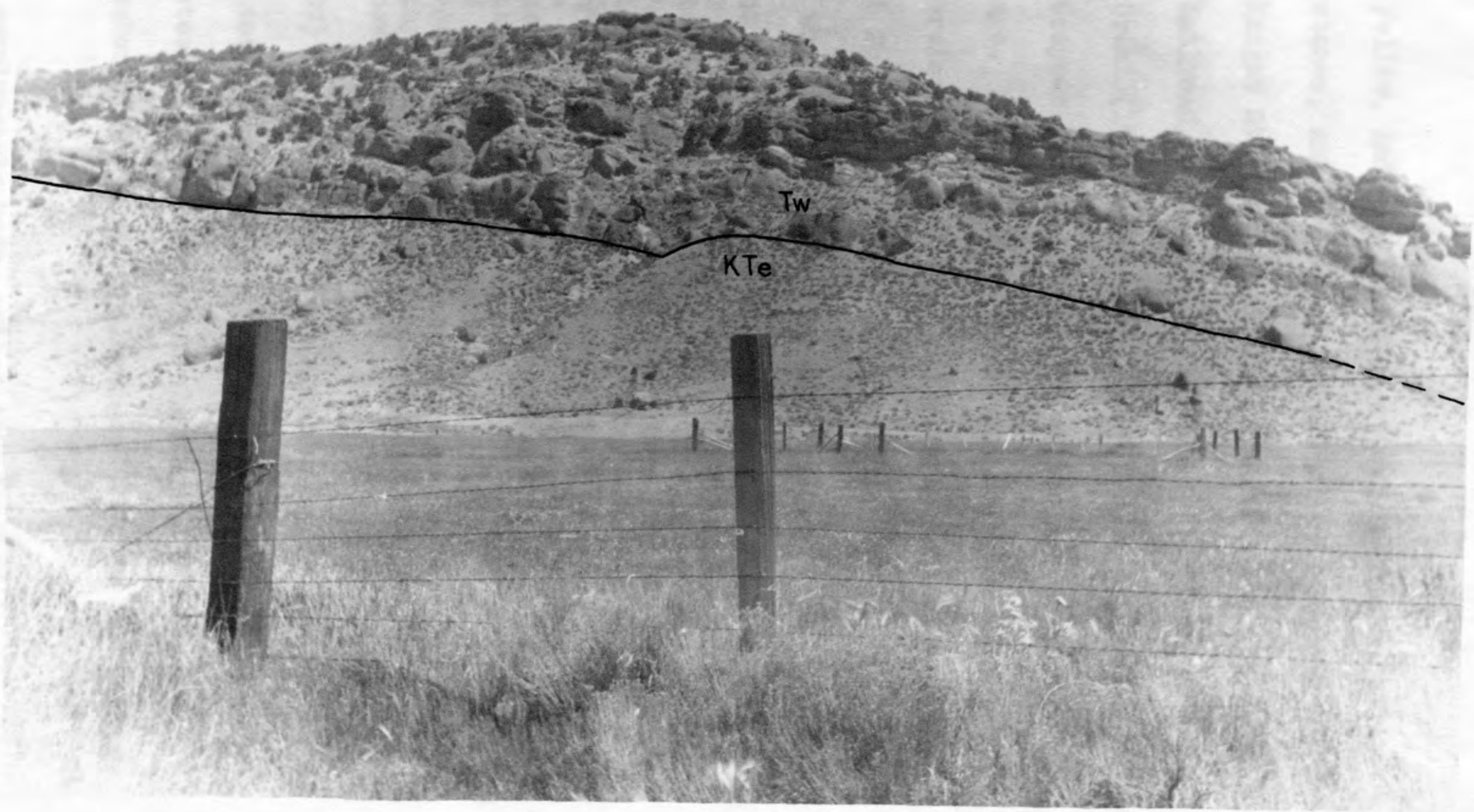

Figure 3. View eastward from Almy, showing Wasatch formation (Veatch's "Almy formation") overlying Evanston formation.

yellow, and gray sandstones, conglomerates, siltstones, and mudstones, in the vicinity of the old Knight Station, on the Union Pacific Short Line Railroad, southeast of Evanston.

Tracy and Oriel (1959), and Gazin (1959), have noted that fresh-water gastropods from the Fowkes formation are of middle to late Eocene age. They further pointed out that the Fowkes formation is therefore younger than, and stratigraphically higher than, the Knight formation.

In view of the above information, Eardley (1959) points out:

> "With the recognition that the Fowkes does not occupy a layered position between the Knight and Almy the relation of the Knight and Almy becomes a problem. In those localities where Veatch shows Knight resting directly on the Almy, the writer (Eardley) has found it impossible to detect any real break. Not being impelled to find a break now that no separating Fowkes is believed to exist, it appears that the Almy is simply a basal unit of the Knight and of no real stratigraphic significance. No means has been found by the writer (Eardley) of recognizing the Almy outside of its type locality just north of Evanston."

Veatch (1907) described the Almy formation as thick, cliff-forming beds of coarse conglomerate (boulders up to one foot in diameter) and interbedded siltstone and claystone. The coarseness and brown color of the Almy distinguished it from the Wasatch formation.

The coarse conglomerate beds, called Almy by Veatch, were traced northward from Evanston 2 to 3 miles by the writer. The conglomerates thin northward to a "knife edge" thickness, approximately 1 mile south of Shell Hollow (see figure 4). The conglomerates were absent north of this vicinity. Wasatch beds interfinger with the conglomerates. About ¼ mile north of Almy Station, red mudstones of the Wasatch rest directly on the Evanston, and the conglomerates overlie the red mudstones.

The writer believes that the strata defined as "Almy" (Veatch) north of Evanston are merely a local, coarse facies of the Knight formation. Therefore, the Almy would not be considered a valid formation name. The writer agrees with the suggestions of Eardley and Tracy and Oriel that the use of the name Almy be discontinued.

The writer further suggests that the orogenic deposits previously referred to as Almy and Knight formations (above), be considered collectively and termed the Wasatch formation. The name "Wasatch" has priority over "Knight".

The Wasatch formation consists of gray, red, and yellow, coarse sandstones and conglomerates, with interbedded, vari-colored siltstones and mudstones. Several thin, light colored, fresh-water limestones occur near the top of the sequence. The sandstones and conglomerates form prominent ledges. Weathered surfaces are often covered with twisted and odd-shaped holes, of all sizes, giving the rocks the appearance of a volcanic scoria.

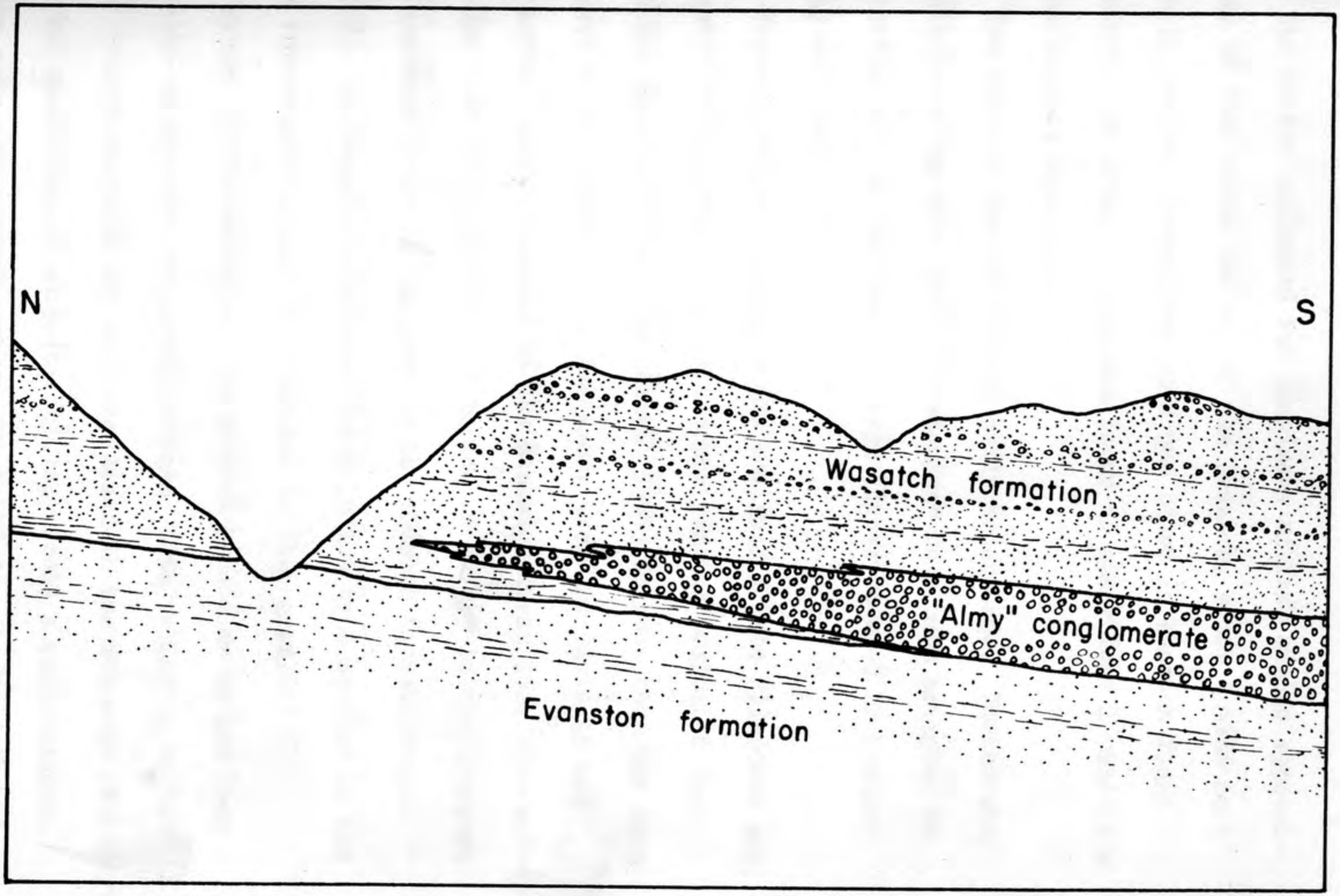

Figure 4. Diagrammatic cross-section, east of Almy, showing interpreted relations of Veatch's "Almy formation" and the Wasatch and Evanston formations.

The writer collected two specimens of fish scales approximately 50 feet below the top of the Wasatch, about 1 mile east of Shell Hollow. Fossilized wood was found in Wasatch float throughout the area. The writer found no other fossil materials in the Wasatch formation.

The Wasatch formation is of early Eocene age. Vertebrate fossils from Veatch's "Knight formation" have been assigned to the Lysite zone of the Wasatch stage (lower Eocene) by Granger (1914) and Gazin (1952).

Veatch's "Almy formation" was assigned a late Paleocene age by Gazin (1942, 1959), from vertebrate remains collected near La Barge, Wyoming. Tracy and Oriel (1959) believe that the beds referred to as "Almy" in the Kemmerer, Wyoming, vicinity are more appropriately included in the Evanston formation. The writer believes that outcrops formerly mapped as "Almy" in the Evanston area are more properly assigned to the Wasatch formation (see page 32). No fossils have been found in the type section of the "Almy formation" to clarify relations in that area.

Burger (1955) described the Wasatch strata as having been deposited on a mature erosional surface, with relief up to 500 feet. This feature is not well expressed in the Evanston vicinity.

The Wasatch basal unconformity represents a major hiatus. Wasatch beds rest unconformably upon rocks from early Cretaceous through Paleocene age, in the area north of Evanston.

Thick, coarse clastics in the Wasatch formation represent an orogenic deposit. Source areas are considered to have been to the west, in the vicinity of the Wasatch Mountains of Utah (Burger, 1955; Eardley, 1959). These thick clastics blanket large areas of southwest Wyoming and Utah, concealing underlying structures and lithologies. Maximum reported thickness of Wasatch strata is about 3,500 feet. Wasatch thickness north of Evanston ranges from 250 feet to approximately 600 feet.

The Wasatch formation consists of red, brown, yellow, and gray claystone, siltstone, sandstone, and conglomerate, with a few thin, fresh-water limestone beds near the top of the sequence.

Wasatch beds interfinger with the Green River and Bridger formations to the east.

Use of the terms "Wasatch group" and, in particular, "Knight formation", has spread throughout southwestern Wyoming and Utah. Tracy and Oriel (1959) feel that the widespread usage of these names is based on somewhat doubtful correlations in many instances.

Bridger (?) formation. Exposures of green-gray to gray, highly altered, volcanic ash were found overlying the Wasatch formation in two localities north of Evanston. This sequence is here tentatively referred to the Bridger formation on the basis of lithology and stratigraphic position. No fossils were found with which to make a definite correlation. One exposure of Bridger (?) was mapped approximately 2 miles south of the Upper Narrows, on the east bench of the Bear River valley. The second exposure was mapped in the southwestern corner of the report area, west of Almy Station.

The Bridger (?) formation, north of Evanston, is a highly decomposed claystone slope-former. The claystone is noticeably bentonitic. Abundant hornblende, biotite, and basic feldspar grains in the claystone strongly suggest a volcanic origin.

Bridger (?) beds rest in fault contact with the Gannett formation south of the Upper Narrows (see figure 5). The contact, or fault trace, is expressed in the topography by a narrow, shallow trough.

Veatch (1907) defined the Bridger formation as:

> "....composed largely of volcanic ash, in places having a marked greenish cast, and containing persistent white calcareous bands, filled with fresh-water shells that are identical in appearance with those found in the Green River and upper Wasatch beds."

The writer visited the type section of the Bridger formation, southeast of Fort Bridger, Wyoming, for the purpose of studying the lithology and collecting petrographic samples. He found the lower few hundred feet of the type Bridger lithologically identical with the Bridger (?) strata north of Evanston.

Samples collected from the Bridger type section and from the

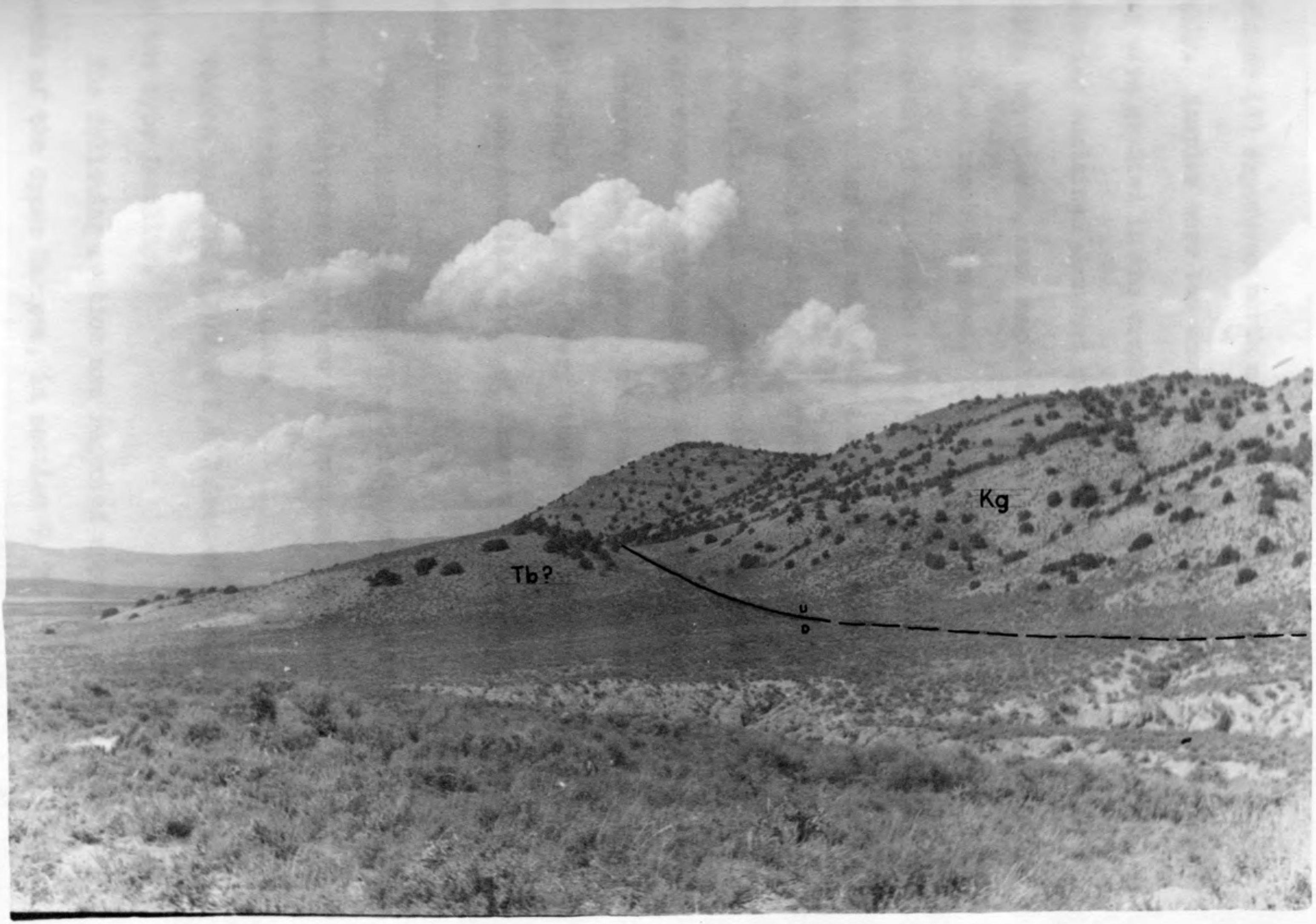

Figure 5. View northeastward from just south of the Upper Narrows, showing Bridger (?) formation in fault contact with the Gannett group. Note topographic trough which marks the fault trace.

Bridger (?) exposures north of Evanston were compared microscopically. Samples were too unconsolidated to prepare thin sections, and were studied in the crushed state. Specimens from both localities contained abundant quartz, calcite, and biotite. Plagioclase, hornblende, and magnetite were present in lesser quantity in samples from both areas. The most abundant, and distinguishing, constituent of all samples studied was an olive green clay mineral, which the writer was unable to identify. This clay mineral is present in tabular and platy crystals and structureless masses. The mineral is slightly pleochroic, has high birefringence, and in a few crystals displays well developed cleavage in one direction.

Petrographic evidence, combined with stratigraphic position and lithology, suggest a very likely correlation of the green volcanic ash deposits north of Evanston with the type Bridger formation.

Veatch (1907) assigned the Bridger formation to the middle Eocene (Bridgerian stage) on the basis of fresh-water mollusks collected from the formation.

Veatch reported 1,200 to 1,800 feet of Bridger formation at the type locality.

The following section was measured approximately 2 miles south of the Upper Narrows, in section 9, T. 17 N., R. 120 W.:

<u>Fowkes formation</u>

Bridger (?) formation	Feet
Claystone; bentonitic; turquoise to olive green, pink, and gray; float covered with small, black siliceous grains, 1 to 2 mm. in diameter; slope-former....................................	206
Covered slope; light gray claystone float............	65
Claystone; bentonitic; pink, maroon, and light gray to gray-green; slope-former....................................	20
Covered slope..	51
Claystone; bentonitic; light brown, gray, green, and red; slope-former...............	12
Total Bridger (?) formation..........................	354

FOWKES FORMATION

Type locality

The Fowkes formation was named by Veatch (1907) from exposures near Fowkes Ranch in the SE$\frac{1}{4}$ of section 32, T. 17 N., R. 120 W. (approximately 9 miles north of Evanston, Wyoming). Veatch interpreted the Fowkes formation as overlying the thick conglomerate sequence, which he named "Almy formation", and underlying the Wasatch formation. This interpretation has since been proven erroneous (Tracy & Oriel, 1959). The Fowkes is now known to be stratigraphically higher than the Wasatch formation.

Age

The Fowkes formation is of late Eocene age. Dwight Taylor identified fresh-water gastropods from the type locality of the Fowkes and from exposures near Sage, Wyoming, as late Eocene or possibly earliest Oligocene (Tracy & Oriel, 1959). According to Gazin (1959):

> "Fresh-water snails collected by the writer (Gazin) in 1953 from the type locality of the Fowkes were determined by Reeside as Eocene in age. These together with samples from other localities mapped by Veatch as Fowkes, were determined by Dwight Taylor as Biomphalaria pseudoammonia, a form reported to be abundant in Bridgerian middle Eocene and known from several Uintan occurrances as established by fossil mammalia. An early

> Oligocene age possibility is also suggested by him from a Beaver Divide occurrance; however, the age relationships there are not entirely clear (Gazin), so that from the evidence of this locality alone the Oligocene possibility may be uncertain."

Fowkes exposures have been reported from the Evanston vicinity northward to the central portion of Fossil Basin in a belt approximately 40 miles wide.

The Fowkes formation rests conformably upon the Bridger (?) formation. The contact between the Bridger (?) and Fowkes formations is not sharp. Deposition appears to have been continuous from the Bridger (?) formation through the Fowkes formation. The contact, therefore, is arbitrarily drawn. The Bridger (?) is characteristically an olive green color, whereas the Fowkes is typically light gray to white. Color difference is the only criterion available for establishing the arbitrary contact. Where Bridger (?) is absent, the Fowkes rests unconformably upon the Wasatch formation. The Fowkes formation occupies the highest stratigraphic position in the area of this report.

Eardley (1959) points out the fact that Fowkes exposures are closely associated with a major zone of normal faulting in southwestern Wyoming and adjacent parts of Utah:

> "Most of the faults cut the Fowkes, but the confinement of the Fowkes volcanic outwash to the belt of faulting indicates that a main drainage way had been established before Fowkes deposition, and therefore, that deformation along the zone had occurred before Fowkes time. The deformation might well have been associated with salt intrusion, solution, and collapse, along with faulting. It

> seems possible, therefore, that the major faults had been established before Fowkes time, and that movement continued on them afterward."

The Fowkes formation consists of light gray to white tuffaceous material, with interbedded thin layers of fresh water limestone, and local, thin lenses of conglomerate.

Fresh water gastropods were collected by the writer from seven localities in the area north of Evanston. Identifications were made by the writer.

Collection taken from the SE ¼ of section 28, T. 18 N., R. 120 W.:

Physa cf. P. longiuscula Meek & Hayden

Physa pleromatis White

Physa sp.

Collection taken from the NE ¼ of section 1, T. 16 N., R. 121 W.:

Physa cf. P. longiuscula Meek & Hayden

Viviparus trochiformis (Meek & Hayden)

Gyraulus aequalis White

Collection taken from the SE ¼ of section 33, T. 17 N., R. 120 W.:

Gyraulus aequalis (White)

Carinulorbis utahensis La Rocque

Planorbis spectabilis White

Collection from the NW ¼ NE ¼ of section 21, T. 18 N., R. 120 W.:

Physa cf. P. longiuscula Meek & Hayden

Physa cf. P. rhomboidea Meek & Hayden

Physa pleromatis White

Physa bridgerensis Meek

Collection from the SW $\frac{1}{4}$ SE $\frac{1}{4}$ of section 33, T. 17 N., R. 120 W.:

Gyraulus aequalis (White)

Gyraulus militaris (White)

Viviparus trochiformis (Meek & Hayden)

Viviparus paludinaeformis (Hall)

Viviparus sp.

Carinulorbis utahensis La Rocque

Holospira cf. H. leidyi (Meek)

Discus cf. D. ralstonensis (Cockerell)

Collection from the NW $\frac{1}{4}$ SW $\frac{1}{4}$ of section 30, T. 18 N., R. 120 W.:

Viviparus trochiformis (Meek & Hayden)

Viviparus paludinaeformis (Hall)

Collection from the SW $\frac{1}{4}$ of section 36, T. 16 N., R. 121 W.:

Gyraulus aequalis (White)

Planorbis spectabilis (White)

Carinulorbis utahensis La Rocque

Viviparus trochiformis (Meek & Hayden)

Holospira cf. H. leidyi (Meek)

The above fossil assemblages have been reported from the late Eocene strata of central Utah (La Rocque, 1960).

Petrography

The writer made petrographic comparisons of samples of Fowkes formation from the Evanston vicinity, and Norwood formation from northeastern Utah, in an effort to clarify relations between these two similar deposits. Suggested correlation of the Fowkes and Norwood by Eardley (1959) led to the petrographic study.

Eleven thin sections were prepared from specimens collected from both Fowkes and Norwood exposures. Thin sections could not be prepared from several samples collected, due to lack of consolidation. These unconsolidated samples were studied in a crushed state.

Tabulated observations from the petrographic analysis follows. Mineral percentages are estimates of the writer.

Sample collected from the Fowkes formation in the mouth of Springs Canyon: NW $\frac{1}{4}$ SW $\frac{1}{4}$, section 33, T. 17 N., R. 120 W., approximately 60 feet above the base of the formation. Hand specimen light gray to very light gray, fine grained, granular texture. Dark minerals are abundant, giving a salt-and-pepper appearance.

Minerals:

Primary	Essential		
		volcanic glass	20%
		quartz	20%
		plagioclase	13%
	Accessory		
		hornblende	3%
		biotite	1%
		magnetite	1%

Secondary Alteration

sericite	1%
hematite	0.5%
limonite	0.5%
Introduced	
calcite	40%

Texture:

Pyroclastic; aphanitic; grains equidimensional, less than 1 mm. in diameter; grains euhedral to subhedral; no orientation.

Special features:

Glass is chiefly in the form of shards. Feldspar and amphibole crystals are predominantly euhedral. Quartz grains are subrounded to rounded.

Observations:

This sample is classified as a crystal tuff, having a rhyodacite composition. Mixture of glass shards, euhedral crystals, and rounded quartz grains indicates that this sediment originated as an ashfall in a region undergoing fluvial and lacustrine sedimentation. Calcite cement, lenticular cross-lamination, and fresh water gastropods in the bed support the concept.

Sample collected from the Fowkes formation in the mouth of Springs Canyon: NW $\frac{1}{4}$ SW $\frac{1}{4}$, section 33, T. 17 N., R. 120 W., approximately 90 feet above the base of the formation. Hand specimen gray to light blue-gray, the blue tint being very pronounced. Granular texture, with grains $\frac{1}{4}$ to $\frac{1}{2}$ mm. in diameter. Abundant dark minerals and scattered dark gray to purple quartzite pebbles give a salt-and-pepper appearance.

Sample studied in the crushed state.

Minerals:

volcanic glass (shards)
quartz
plagioclase
hornblende
biotite
magnetite
hematite
limonite
calcite
sericite

Index of refraction of the glass:

between 1.51 and 1.52

Sample collected from the Fowkes formation approximately 1 mile north of Christensen Hollow, on the east-facing slope of Whitney Canyon: NE $\frac{1}{4}$ NE $\frac{1}{4}$, section 29, T. 17 N., R. 120 W., about 150 feet above the base of the formation. Very fine grained, somewhat granular texture. Abundant dark minerals and small grains of dark gray to purple quartzite give a salt-and-pepper appearance. (Crushed sample).

Minerals:

volcanic glass (shards)

quartz

plagioclase

hornblende

magnetite

hematite

limonite

calcite

clay minerals

Index of refraction of the glass:

between 1.51 and 1.52

Sample collected from the Fowkes formation approximately 1 mile north of Christensen Hollow, on the east-facing slope of Whitney Canyon: NE $\frac{1}{4}$ NE $\frac{1}{4}$, section 29, T. 17 N., R. 120 W., approximately 25 feet above the base of the formation. Hand specimen very light blue to light blue gray. Very fine grained, massive texture. Scattered dark minerals give a salt-and-pepper appearance. Notable is a one-half inch band of rounded clay pebbles, $\frac{1}{2}$ to 1 mm. in diameter.

Minerals:

Primary	Essential		
		volcanic glass	25%
		quartz	25%

plagioclase 5%

Accessory

hornblende 1%

biotite 1%

magnetite 0.5%

Secondary Alteration

sericite 10%

limonite 0.5%

Introduced

calcite 33%

Texture:

Pyroclastic; aphanitic; crystals anhedral to subhedral; grains less than 1 mm. in diameter; no preferred orientation.

Special features:

The glass fragments are in the form of shards and pumice. Shards are delicate and unbroken. Vesicles in the pumice fragments are notably elongated.

Observations:

This specimen is classified as a crystal tuff, having a rhyodacite composition. The primary process of deposition represented here is a volcanic ashfall. Delicate, unbroken shards suggest little or no mechanical transportation after original deposition.

Sample collected from the Fowkes formation due west of Almy Station. Taken along roadside on the west side of Bear River Valley, approximately ¼ mile south of the mapped area, about 35 feet above the base of the formation. Hand specimen light blue-gray. Very fine grained, massive texture. Dark minerals occur in clusters.

Sample studied in the crushed state.

Minerals:

volcanic glass (shards)
plagioclase
quartz
hornblende
magnetite
hematite
limonite
calcite
clay minerals

Index of refraction of the glass:

between 1.51 and 1.52

Sample collected from the Fowkes formation due west of Almy Station. Taken along roadside on the west side of Bear River Valley, approximately ¼ mile south of the mapped area, about 50 feet above the base of the formation. Hand specimen light blue-gray, with scattered grains of biotite and hornblende giving a salt-and-pepper appearance. Medium grained, granular texture.

Minerals:

Primary	Essential		
		plagioclase	30%
		volcanic glass	10%
		quartz	5%
	Accessory		
		hornblende	5%
		magnetite	3%
		biotite	1%
		clay minerals	9%
Secondary	Alteration		
		clay minerals	6%
		hematite	0.5%
		limonite	0.5%
	Introduced		
		calcite	30%

Texture:

Pyroclastic; hypocrystalline; phaneritic (grains 1 to 5 mm. in diameter); crystals are anhedral to euhedral.

Special features:

Glass fragments are rounded to subrounded. Most of the crystals display alteration borders. Massive calcite fills veins and surrounds clusters of crystals and glass.

Observations:

This specimen is classified as a tuffaceous sediment. Mechanical transportation following the original ashfall is indicated by the roundness of the glass fragments and dominant anhedral and subhedral form of the crystals. Weathering of the sample has attained a moderate degree. Much of the glass is devitrified, and many of the minerals display alteration borders.

Sample collected from the Fowkes formation due west of Almy Station. Taken along roadside on the west side of Bear River Valley, approximately ¼ mile south of the mapped area, about 75 feet above the base of the formation. Hand specimen light gray to gray. Extremely fine grained, massive texture. Grains of dark gray to purple quartzite, ½ to 1 mm. in diameter, are scattered throughout the specimen. Numerous shell fragments are scattered throughout the sample. Small fractures, filled with chalk-white clay, cut across grains and shell fragments.

Minerals:

Primary	Essential	
	volcanic glass	12%
	plagioclase	6%
	quartz	4%
	Accessory	
	cristobalite	1%
	organic material	1%

	magnetite	0.5%
	clay minerals	25%
Secondary	Alteration	
	clay minerals	45%
	hematite	0.25%
	limonite	0.25%
	Introduced	
	opal	5%

Texture:

Pyroclastic; aphanitic (grains equidimensional); glass and quartz grains are angular; crystals are subhedral to euhedral; no preferred orientation noted.

Special features:

Organic material is present as long, curved fragments. This material exhibits wavy extinction, fibrous texture, and pleochroism. Nearly all veins and vesicles are filled with opal and cristobalite. Many of the glass fragments exhibit alteration rims of clay minerals. The central portions of several glass fragments are opalized. Several crystals have been completely altered to clay minerals, retaining the original crystal outline.

Observations:

This specimen is classified as a vitric tuff. Mechanical transportation after original deposition is not apparent. The sample has undergone extensive weathering. Most of the volcanic glass is devitrified and the mineral grains have been altered to clays.

Sample collected from the Fowkes formation approximately 2,000 feet north of the mouth of Christensen Hollow: SW $\frac{1}{4}$ NE $\frac{1}{4}$, section 29, T. 17 N., R. 120 W., about 40 feet below the top of the formation. Hand specimen light gray to gray. Fine grained, granular texture. Small, rounded pebbles of clay disseminated throughout the sample. Scattered dark minerals give a salt-and-pepper appearance. Weathered surface is very rough and pitted. Sample studied in the crushed state.

Minerals:

volcanic glass (shards)
quartz
plagioclase
hornblende
biotite
hematite
limonite
clay minerals
calcite

Index of refraction of the glass:

approximately 1.51

Sample collected from the Fowkes formation approximately 2,000 feet north of the mouth of Christensen Hollow: SW $\frac{1}{4}$ NE $\frac{1}{4}$, section 29,

T. 17 N., R. 120 W., about 60 feet below the top of the formation. Hand specimen light gray. Extremely fine grained to massive texture. Numerous pebbles of clay scattered throughout the sample.

Minerals:

Primary	Essential		
		volcanic glass	40%
		quartz	1%
	Accessory		
		magnetite	1%
Secondary	Alteration		
		clay minerals	3%
	Introduced		
		calcite	55%

Texture:

Pyroclastic; aphanitic; holohyaline; and vitrophyric.

Special features:

The volcanic glass consists primarily of delicate shards. Few pumice fragments are present. The volcanic glass and mineral crystals are cemented together with calcite. The calcite occurs as massive aggregates of minute crystals.

Observations:

This specimen is classified as a vitric tuff. Mechanical transportation after the original deposition of the ash is not apparent. This sample shows very little sign of weathering.

Sample taken from the Fowkes formation in a roadcut between Springs Canyon and Christensen Hollow: NE $\frac{1}{4}$ NE $\frac{1}{4}$, section 32, T. 17 N., R. 120 W., about 50 feet below the top of the formation. Hand specimen gray to gray brown. Medium grained, granular texture. Scattered hornblende and biotite grains give a salt-and-pepper appearance. Sample studied in the crushed state.

Minerals:

volcanic glass (angular)

quartz

plagioclase

hornblende

biotite

magnetite

hematite

limonite

clay minerals

calcite

Index of refraction of the glass:

approximately 1.51

Sample collected from the Fowkes formation approximately 1,000 feet west of the dirt road where it crosses the hilltop just south of Springs Canyon: SW $\frac{1}{4}$ SE $\frac{1}{4}$, section 32, T. 17 N., R. 120 W., about 15 feet below the top of the formation. Hand specimen gray to gray brown limestone. Very fine grained, massive texture. Clay pebbles scattered throughout the sample. Fractures are filled with opal. Sample studied in the crushed state.

Minerals:

calcite

quartz

opal

magnetite

hematite

limonite

No volcanic glass is present in this sample. This represents a fresh water limestone bed within the Fowkes formation.

Petrography of Norwood tuff

Sample collected from the Norwood tuff approximately ¼ mile east of Utah Highway 66, along the road which leads up Norwood Canyon, near Porterville, Utah. Sample was taken from the top of the formation. Hand specimen light gray. Medium grained, massive texture. Rounded clay pebbles are scattered throughout the sample.

Minerals:

Primary	Essential		
		volcanic glass	60%
		plagioclase	3%
		orthoclase	1%
		quartz	1%

	Accessory	
	biotite	1%
	magnetite	1%
Secondary	Alteration	
	clay minerals	4%
	Introduced	
	calcite	30%

Texture:

Pyroclastic; holohyaline; and pumiceous. Crystals are 1 to 2 mm. in diameter, are subhedral, and are equidimensional.

Special features:

The glass fragments are primarily pumice, with elongated vesicles. Massive calcite fills vesicles and fractures. No preferred orientations observed.

Observations:

This specimen is classified as a pumice. Mechanical transportation after the original ashfall is not apparent. Weathering has been slight, with very little devitrification of the volcanic glass.

Sample collected from the Norwood formation approximately $\frac{1}{4}$ mile east of Utah Highway 66, along the road which leads up Norwood Canyon, near Porterville, Utah. Sample was taken from about 75 feet below the top of the formation. Hand specimen light gray to gray brown. Extremely fine grained, massive texture.

Minerals:

Primary	Essential		
		volcanic glass	25%
		quartz	5%
		plagioclase	1%
		orthoclase	1%
	Accessory		
		biotite	1%
		magnetite	1%
		clay minerals	30%
Secondary	Alteration		
		clay minerals	15%
		hematite	0.5%
		limonite	0.5%
	Introduced		
		calcite	20%

Texture:

Pyroclastic; vitrophyric; and aphanitic. Crystals subhedral to anhedral.

Special features:

The volcanic glass consists of shards and pumice (about 80% shards, 20% pumice, of the total glass). The glass fragments are delicate and unbroken. Calcite occurs as a fine grained aggregate cement, filling fractures and vesicles.

Observations:

This specimen is classified as a vitric tuff, having the composition of a quartz latite. Mechanical transportation after the original ashfall is not indicated. Weathering of this sample has been extensive.

Sample collected from the Norwood formation approximately $\frac{1}{4}$ mile east of Utah Highway 66, along the road which leads up Norwood Canyon, near Porterville, Utah. Sample was taken from about 150 feet below the top of the formation. Hand specimen light gray brown. Conglomeratic texture. Very fine grained matrix with $\frac{1}{4}$ to $\frac{1}{2}$ inch diameter pebbles of dark gray to purple quartzite. Rounded clay pebbles disseminated throughout the specimen. A few, scattered biotite flakes are visible to the naked eye. Sample studied in the crushed state.

Minerals:

volcanic glass
quartz
plagioclase
biotite
magnetite
clay minerals

Index of refraction of the glass:

between 1.51 and 1.52

Sample collected from the Norwood formation approximately $\frac{1}{4}$ mile west of Peterson, Utah, along large irrigation canal. Specimen taken from the middle portion of the exposure. Hand specimen light gray to gray. Very fine grained, massive texture. Few scattered dark minerals are barely visible with a hand lens.

Minerals:

Primary	Essential		
		volcanic glass	50%
		quartz	12%
		plagioclase	2%
	Accessory		
		biotite	1%
		magnetite	1%
		clay minerals	10%
Secondary	Alteration		
		hematite	1%
		limonite	1%
		clay minerals	22%

Texture:

Pyroclastic; vitrophyric; and aphanitic. Crystals are anhedral.

Special features:

The volcanic glass is wholly comprised of shards. The majority of the clay minerals appear to be the result of devitrification of the glass, although a small portion appears to be a result of alteration of feldspars and biotite.

Observations:

This specimen is considered a vitric, or welded, tuff, having a composition of a rhyodacite. Mechanical transportation after the original ashfall is not apparent. Consolidation is due to silicification, or "welding" of the glass. Extensive devitrification of the volcanic glass is evident.

Sample collected from the Norwood formation approximately ¼ mile west of Peterson, Utah, along large irrigation canal cut. Specimen taken from the base of the exposure. Hand specimen very light gray to white. Extremely fine grained, massive texture. A very few biotite grains are visible with a hand lens. Sample is very brittle and breaks into conchoidal fractures.

Minerals:

Primary	Essential		
		volcanic glass	85%
		quartz	1%
	Accessory		
		magnetite	1%
Secondary	Alteration		
		clay minerals	13%

Texture:

Pyroclastic; holohyaline; vitrophyric; and aphanitic.

Special features:

Shards are abundant, comprising over one-half of the volcanic glass. Fractures are filled with opaque clay minerals.

Observations:

This specimen is classified as a vitric tuff. Mechanical transportation after the original ashfall is not apparent. The purity of the ash, along with the extreme fine grained texture, suggests possible eolian sorting at some distance from the parent magma.

Sample collected from the Norwood formation approximately 1,500 feet north of the junction of U. S. Alternate Highway 189 and Utah Highway 196 north of Peoa, Utah. Specimen taken from exposures on the east side of the road, from a dark colored volcanic bed overlying light gray tuffs. Hand specimen dark gray, mottled. Medium to coarse grained, prophyritic texture. Abundant phenocrysts of plagioclase, hornblende, and biotite, with a small amount of quartz. Sample studied in the crushed state.

Minerals:

plagioclase
quartz
biotite
hornblende
volcanic glass
clay minerals

calcite

magnetite

hematite

limonite

Index of refraction of the glass:

between 1.52 and 1.53

Sample collected from the Norwood formation approximately 1,500 feet north of the junction of U. S. Alternate Highway 189 and Utah Highway 196 north of Peoa, Utah. Specimen taken from exposures on the east side of the road, about 60 feet below the top of the tuffaceous strata. Hand specimen gray to gray brown. Very fine grained, massive texture. Rounded clay pebbles disseminated throughout the specimen.

Minerals:

Primary	Essential		
		volcanic glass	35%
		plagioclase	5%
		quartz	4%
	Accessory		
		biotite	1%
		magnetite	1%
		clay minerals	15%
Secondary	Alteration		
		clay minerals	19%

Introduced

calcite 20%

Texture:

Pyroclastic; vitrophyric; and porphyritic. Crystals euhedral to subhedral.

Special features:

The volcanic glass is comprised of about one-half angular fragments, two-fifths shards, and one-tenth pumice fragments. A large portion of the glass has been devitrified. Fine grained calcite fills fractures, vesicles, and interstices.

Observations:

This specimen is classified as a vitric tuff. A few of the grains are well rounded, suggesting some mechanical transportation after the original ashfall. The porphyritic texture of this sample, when compared to the fine grained texture of the tuff samples to north and east, suggests that this specimen may have been deposited closer to the source vent (Williams, Turner, and Gilbert, 1955; p. 151).

Sample collected from the Norwood formation approximately 1,500 feet north of the junction of U. S. Alternate Highway 189 and Utah Highway 196 north of Peoa, Utah. Specimen taken from exposures on the east side of the road, about 100 feet below the top of the tuffaceous strata. Hand specimen gray to gray brown. Very fine grained, massive texture. Rounded pebbles of clay abundant.

Minerals:

Primary	Essential		
		volcanic glass	35%
		plagioclase	10%
		quartz	2%
	Accessory		
		magnetite	1%
		biotite	1%
		clay minerals	30%
Secondary	Alteration		
		clay minerals	15%
		hematite	1%
		limonite	1%
	Introduced		
		calcite	4%

Texture:

Pyroclastic; vitrophyric; and porphyritic. Phenocrysts are about 1 to 5 mm. in diameter. Crystals are subhedral to anhedral.

Special features:

The volcanic glass consists primarily of pumice fragments, with a few shards. Most of the glass is devitrified. Fine grained calcite fills vesicles and interstices.

Observations:

This specimen is classified as a pumice. Mechanical transportation after the original ashfall is not apparent. No preferred orientations or flow structures observed.

The petrographic analyses of Fowkes and Norwood samples reveal several similarities and dissimilarities between the two formations. The most characteristic feature of the samples studied is the high content of volcanic glass, particularly in the form of shards and pumice. Minerals present in the samples from both formations are very nearly the same, although the relative quantities of individual minerals vary. The indices of refraction of the volcanic glass contained in both the Fowkes and Norwood formations are very similar, being between 1.51 and 1.52. This indicates glass of approximately 67% silica (Williams, Turner, and Gilbert, 1955; p. 28, fig. 7).

Volcanic glass constitutes about 21% (average) of the Fowkes formation, and about 48% (average) of the Norwood formation. Feldspars, quartz, and heavy minerals appear to be much more abundant in the Fowkes formation than in the Norwood formation.

Investigations of thin sections indicate that there has been very little mechanical transportation of the material after the original deposition of the volcanic ash. Field studies, however, give strong evidence of fluvial and lacustrine processes in both the Fowkes and Norwood formations. Prominent lenticular cross-lamination, coarse conglomerate lenses, and fresh-water limestone beds are common in both formations (see figures 6 and 7). The writer feels that the broader evidence from the field warrants the conclusion that fluvial and lacustrine processes have played an important role in the present distribution and lithologies of the Fowkes and Norwood formations.

Correlation

The composition of the Fowkes formation is close to that of a rhyodacite, whereas the composition of the Norwood tuff is close to that of a latite or quartz latite. The range in composition, however, appears to be nearly as great within each formation as between the two formations.

Paleontological evidence from the Fowkes and Norwood formations suggest a close time equivalence. Fresh-water gastropods from the Fowkes formation have been assigned to the upper Eocene by Gazin (1959), and by the writer (see pages 42 and 43). Vertebrate remains from the Norwood formation have been identified as upper Eocene forms (Gazin, 1959; Eardley, personal communication).

The Fowkes and Norwood formations occupy the same stratigraphic interval and are of nearly identical lithologies.

Exposures of the Norwood tuff exhibit increasingly fine grained texture from south to north. Textures of the Fowkes samples correspond closely with the textures of the Norwood samples taken from Porterville and Peterson, Utah. This lateral texture gradation is consistent with the theory that the Park City volcanic field, to the southwest, may be the source area of both the Fowkes and Norwood (Eardley, personal communication).

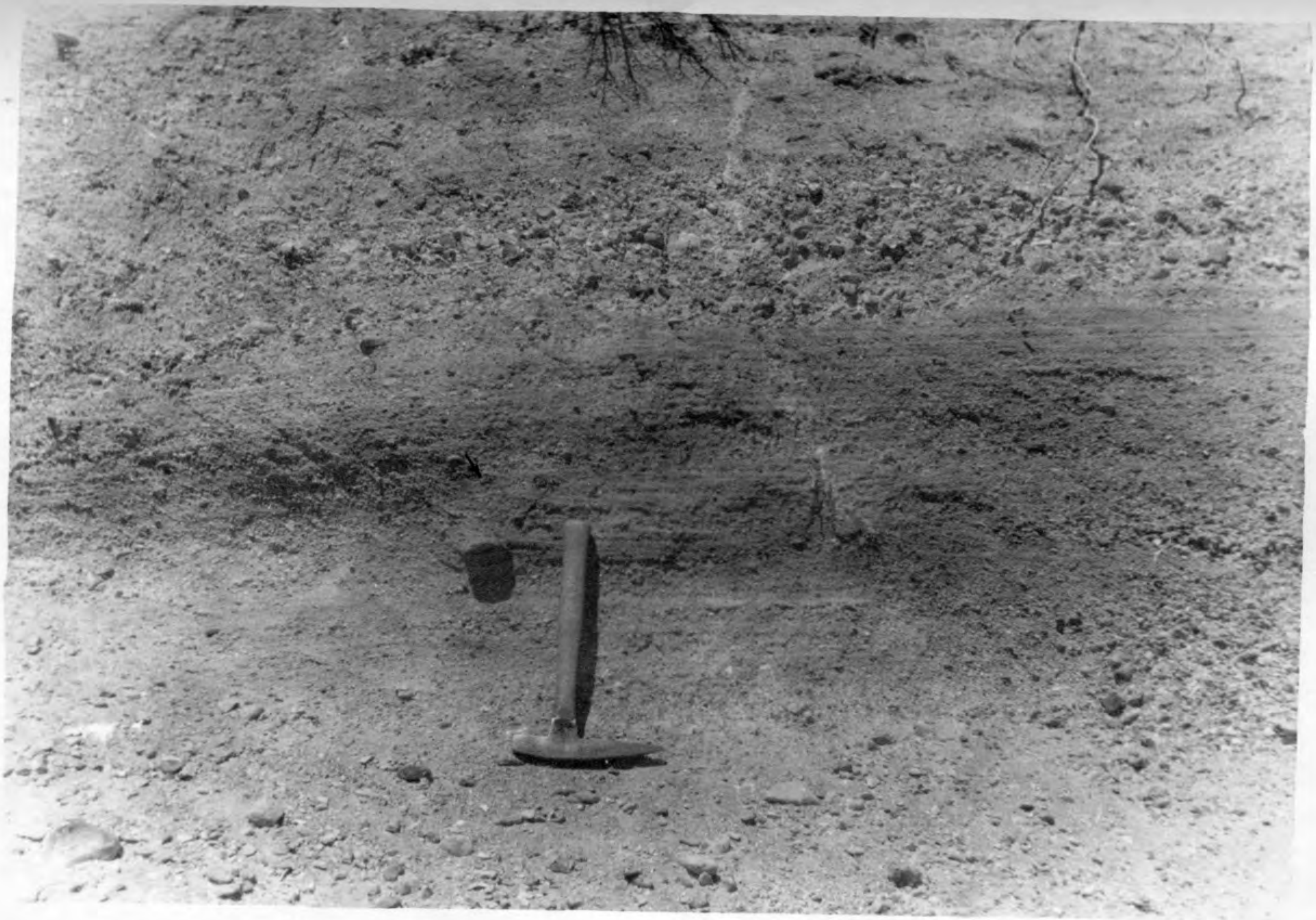

Figure 6. Fowkes formation outcrop in Whitney Canyon, showing local conglomerate lenses and slight cross-lamination (arrow).

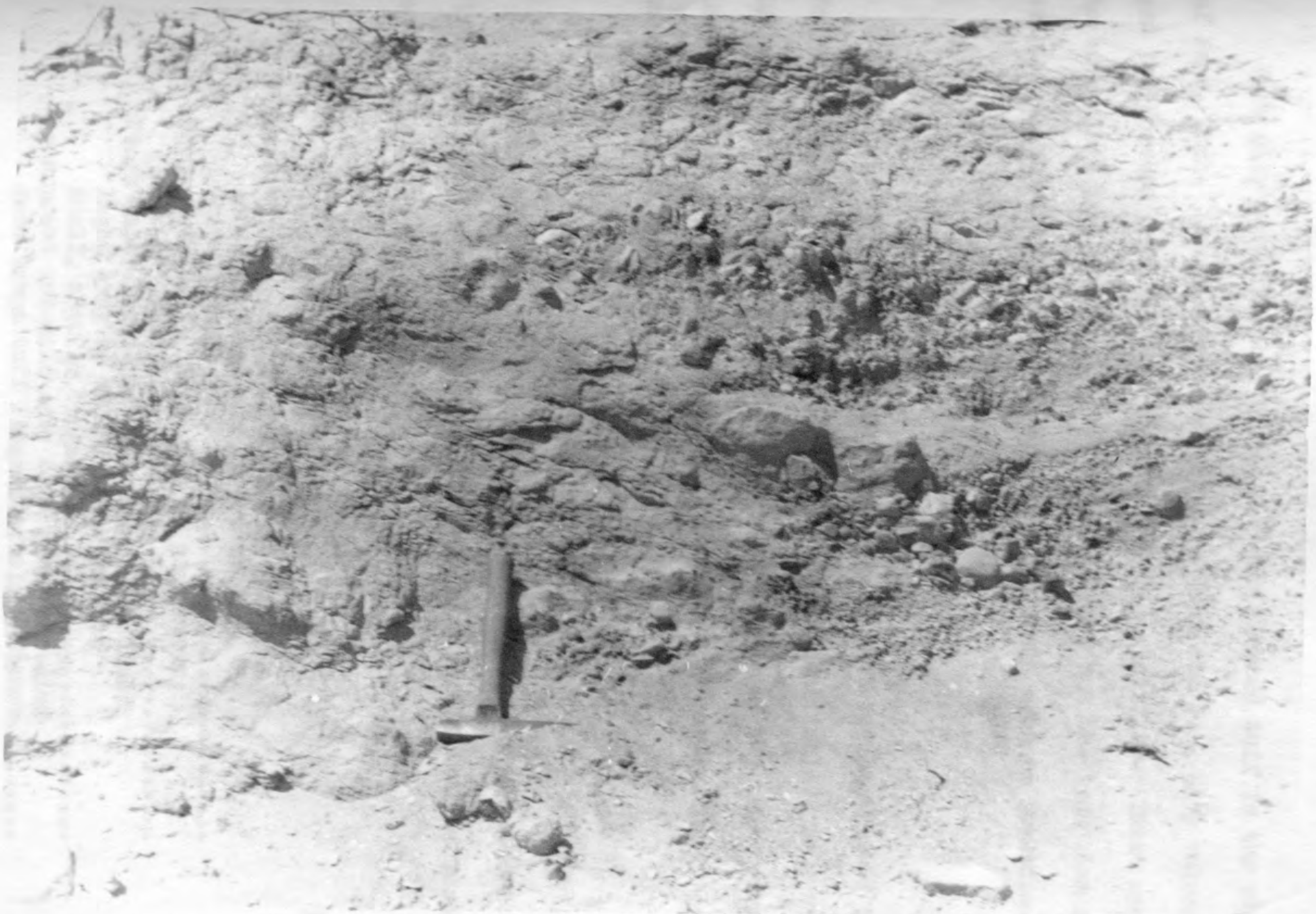

Figure 7. Fowkes formation outcrop in Whitney Canyon, showing local conglomerate lenses.

Park City volcanics are found overlying Norwood tuff in the vicinity of Peoa, Utah. The mineral composition of both the Park City volcanics and the Norwood tuff, in this locality, are very similar. There appears to be a close association of the two formations, but the true time and origin relationships are not known and must remain open to question.

Conclusions

In view of the evidence, the writer feels that correlation of the Fowkes formation with the Norwood formation is justifiable. This correlation would necessitate the discontinuance of use of the name "Norwood" in preference to the name "Fowkes", as suggested by Eardley (1959), the name "Fowkes" having priority (Veatch, 1907).

Measured section

Thickness of the Fowkes formation is not everywhere equal, due to structural relations and erosion. The following section was measured in section 33, T. 17 N., R. 120 W.:

<u>Alluvium</u>

Fowkes	Feet
Covered slope; light gray claystone float; contains fragments of crystalline, white limestone..................................	83
Decomposed tuff; light gray to gray brown; slope former..................................	9
Fresh water limestone; massive crystalline; light gray to white; weathers into small, angular fragments........................	2
Decomposed volcanic ash; dark gray; contains some large tuff fragments; slope former.........	9

Tuff; gray to gray brown; salt-and-pepper appearance; slight lenticular cross-lamination; contains inclusions of white claystone or mudstone........................	8
Siltstone and claystone; gray to white; slope-former; float contains small fragments of crystalline limestone and tuff......................................	59
Total exposed Fowkes formation........................	170

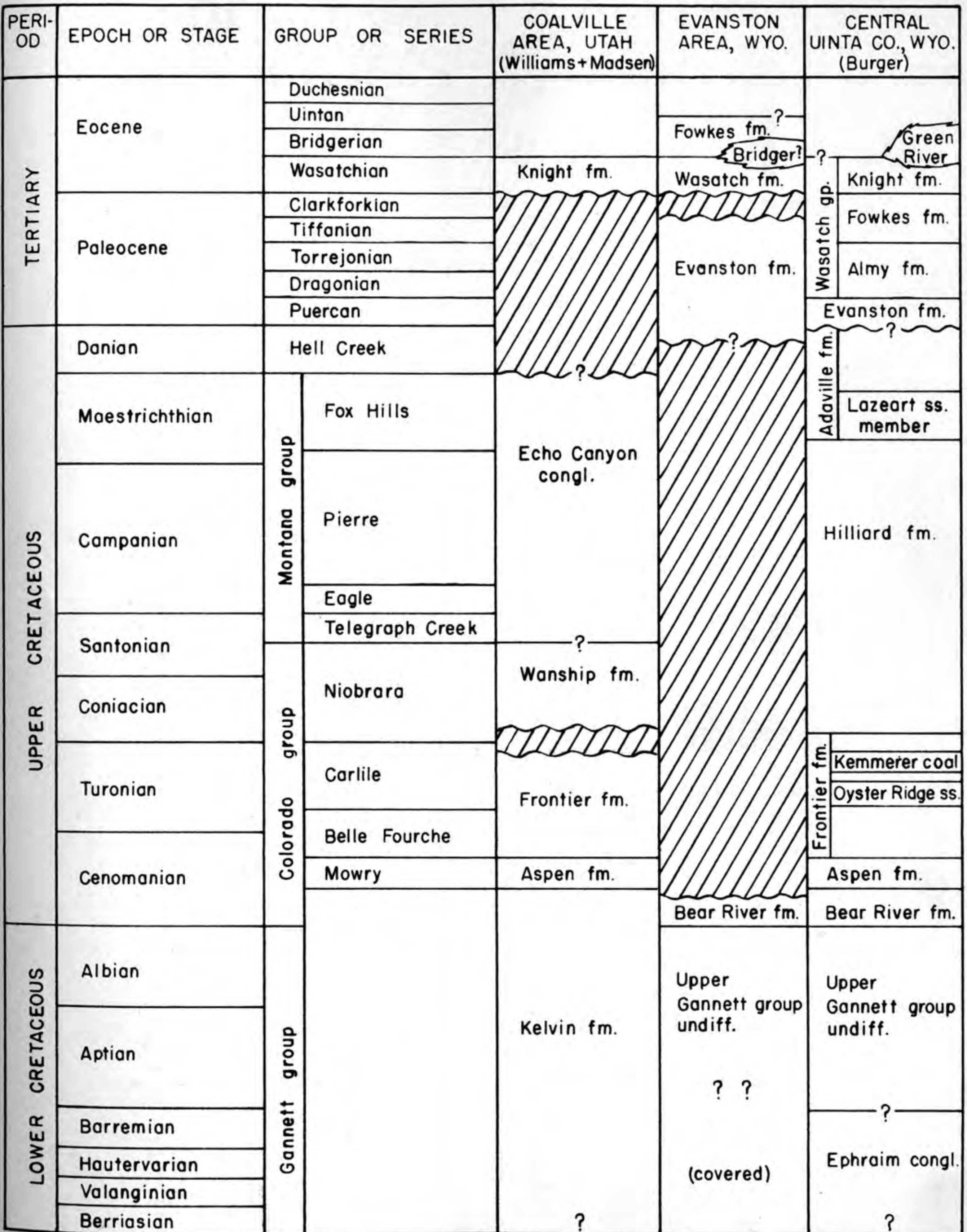

Figure 8. Stratigraphic Correlation Chart

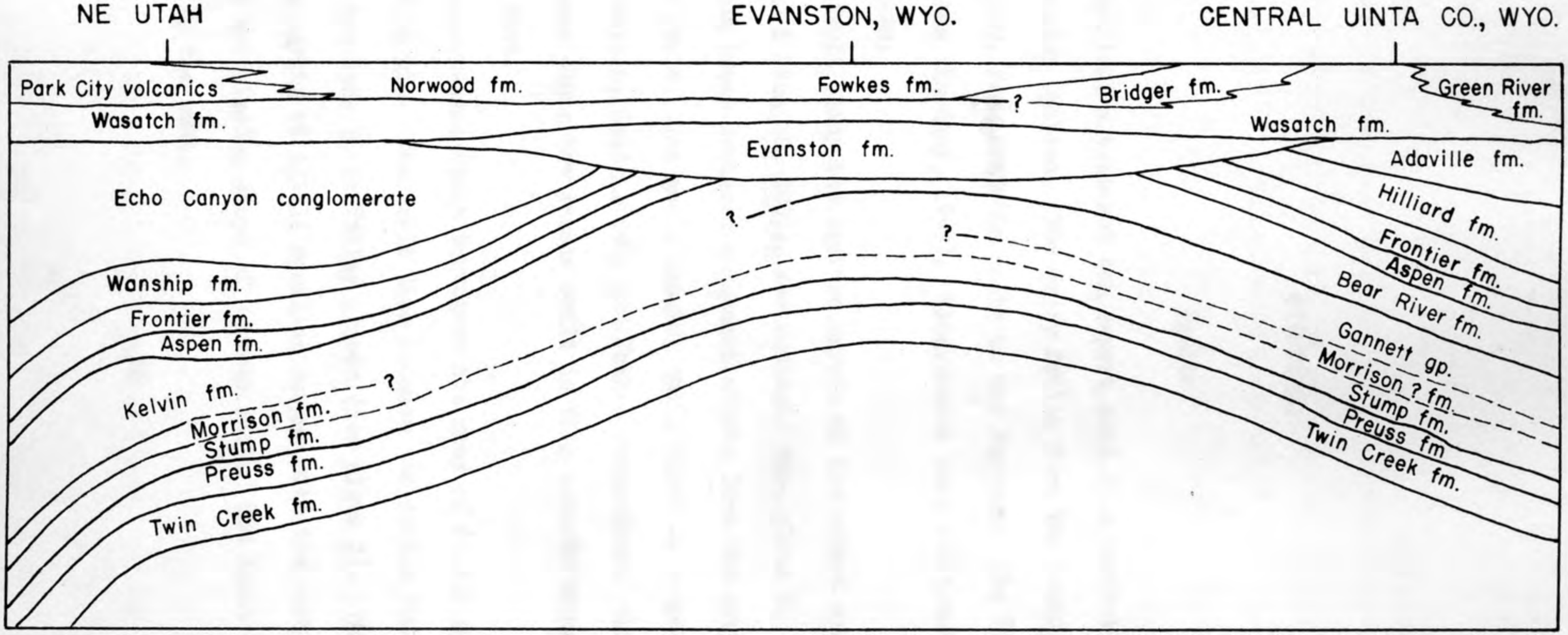

Figure 9. Idealized cross-section from northeastern Utah to central Uinta County, Wyoming, showing interpreted stratigraphic relationships (thicknesses and structures are not necessarily accurately represented).

STRUCTURE

Faults

Normal faults transect the report area in a north-trending, parallel and en echelon pattern. Two major faults form the boundaries of the Bear River Valley, from Evanston north to the Narrows. The valley is a graben between them (Eardley, 1959). Escarpments mark the trace of these two major faults.

The fault along the eastern margin of the report area is called the Acocks Fault (Veatch, 1907), see Geologic Map, plate 2. Complexly folded and faulted Lower Cretaceous Gannett strata form the east, footwall, block of Acocks Fault. The west, hanging wall, block is composed of the east dipping Wasatch, Bridger (?), and Fowkes formations. Maximum vertical displacement along the Acocks Fault in this area is approximately 3,300 to 3,500 feet.

A major normal fault truncates the nose of Alkali Syncline along its southwest margin. The fault lies between the Acocks Fault and the east fault of the Bear River Valley graben (see plate 2). The fault along the southwest margin of Alkali Syncline merges with the east river valley fault along the west-facing slope of Narrows Hill. The fault borders Alkali Syncline on the west.

Bridger (?) beds have been brought into contact with the Gannett group along the fault which cuts the Alkali Syncline nose. A narrow, shallow topographic trough separates the Bridger (?) and Gannett strata, marking the fault trace. Maximum vertical displacement along the fault is about 3,350 feet.

The magnitudes and true dips of the graben faults along the river valley are obscure. Escarpments on each side of the river valley are upheld by Wasatch and Fowkes strata. The valley floor is covered by thick alluvial deposits.

Another large normal fault was mapped in the southern part of the report area. The fault strikes north, extending from the vicinity of Shell Hollow north to the mouth of Springs Canyon (Veatch's "Almy fault"). At the mouth of Shell Hollow, Wasatch and Fowkes strata rest in fault contact with the Bear River formation (see figure 10). Maximum vertical displacement is approximately 1,400 to 1,500 feet.

A complex zone of faulting occurs in the mouth of Springs Canyon. A fault zone trends northwesterly along the length of Springs Canyon, and appears to intersect the Shell Hollow fault, mentioned above, in the mouth of the canyon. Relations are obscure in this locality. No direct evidence was found which would clarify the problem. Beyond the mouth of Springs Canyon, the faults are covered by Fowkes deposits.

Another major normal fault is expressed by a prominent escarpment along the western margin of the area in the vicinity of Almy. The Fowkes formation has been lowered along the fault into contact with the lower

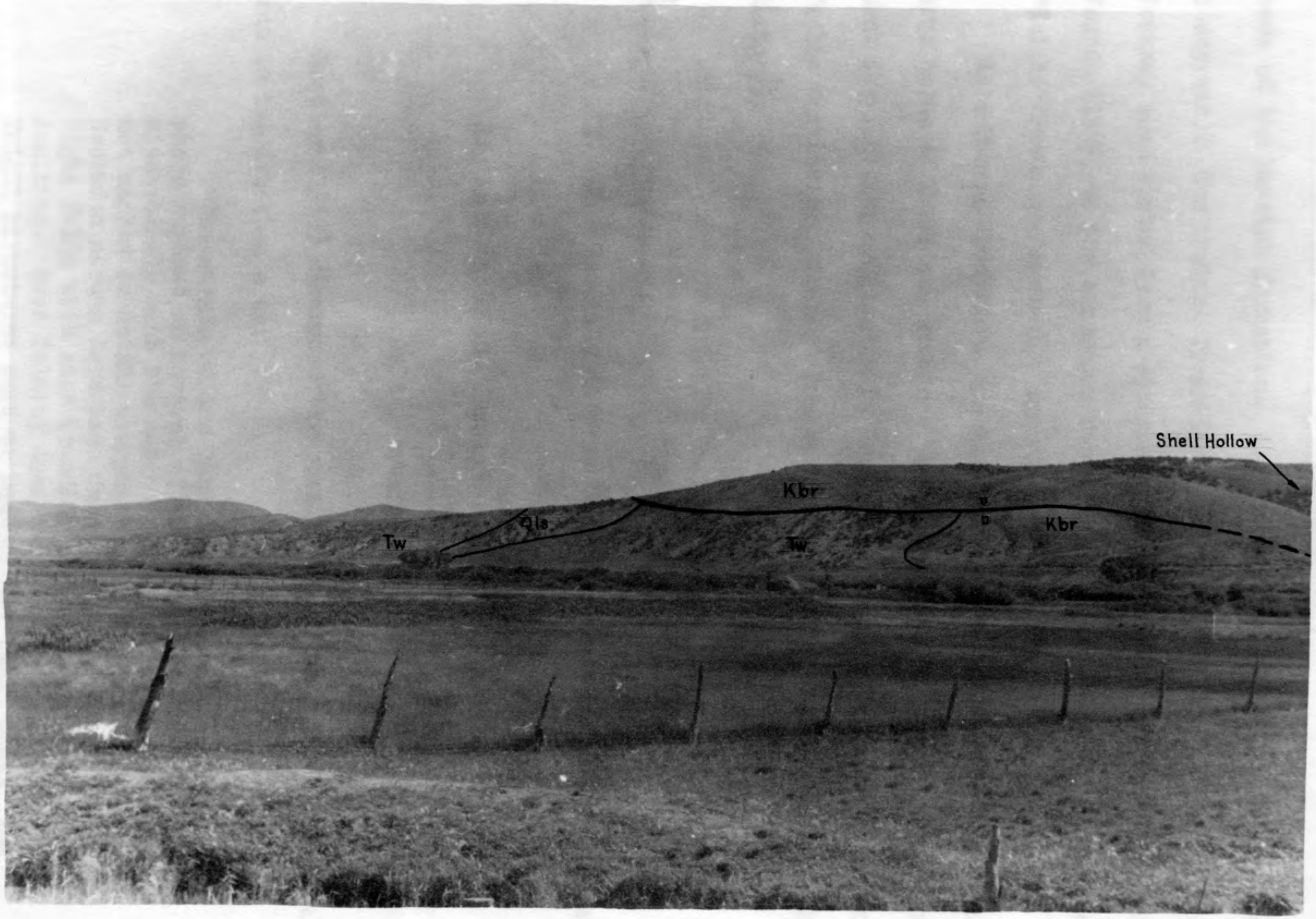

Figure 10. View northeastward from the southern extremity of the area, showing the fault trace along the mouth of Shell Hollow.

beds of the Wasatch formation. Both formations dip slightly west (2 to 5 degrees). The Wasatch formation appears to rest conformably upon the Fowkes, when viewed from a distance. This apparent relationship led Veatch (1907) to the erroneous subdivision of the "Wasatch group", with "Knight" resting conformably upon Fowkes (see figure 11).

Late Eocene formations are involved in the normal faulting of the area north of Evanston, Wyoming. Eardley (1959) suggests the probability that the faulting originated in pre-Fowkes time, with movement along the faults continuing into post-Fowkes time (refer to section on Geologic History).

Origin of the normal faults in this area may be due to either, or both, of the following:

1. Late Laramide deformation following deposition of Wasatch clastics.
2. Salt anticline development.

Salt intrusion (?)

Eardley (1959) discussed the possibility of salt anticline development in the Evanston area:

> "The strata of the Beckwith formation, especially where exposed in several of the upfaulted blocks, strike discordantly with the Basin and Range faults. Although not mapped in detail everywhere, it appears evident that Beckwith strata have been deformed into rather small, tight folds with axes trending at angles to the belt of faulting. Such folding does not characterize the pre-Knight structures east or west of the fault zone. The Utah Southern well drilled in T. 6 N., R. 8 E. encountered

Figure 11. View westward from Almy, showing Fowkes beds in fault contact with Wasatch strata.

> considerable salt in the Beckwith, and this plus the discordant folding leads to the thought that the zone in pre-Basin and Range faulting (pre-late Eocene) may have been a salt anticline type of structure.
>
> The local development of the Evanston formation and its deposition on the truncated Bear River formation, found nowhere outside the fault zone, support the theory.
>
> A conflict in the interpretation of the origin of the normal faults of the fault zone is evident; are they strictly the result of salt anticline mechanics and therefore limited to the superficial strata above the mother salt, or are they of Basin and Range type with the connotation that they penetrate deeply into the crust and are of deep-seated origin? It is difficult to find evidence that bears one way or the other on the problem."

Salt was noted in an oil test hole (Slosson and Associates no. 1 Cole) in T. 16 N., R. 121 W., by Schick (1959, fig. 3). The salt occurs in the Beckwith sequence.

Complex structures in the mouth of Springs Canyon further suggest salt anticline structures. Several small blocks of Wasatch and Fowkes strata, with tumbled, chaotic attitudes, occupy this area. It is not clear whether these chaotic blocks are related to the convergence of two large normal faults (see page 75), or are possible slump features related to salt movements. Relief in this locality is low. The writer therefore feels that the blocks are probably not landslide features.

Exposures of Bear River strata in Shell Hollow exhibit inconsistent strikes and dips (see plate 2). The Evanston formation progressively overlaps the Bear River beds to the north of Shell Hollow. Strikes of the Evanston beds range from slightly west of north in Shell Hollow, to westerly along the north facing slope of Springs Canyon (see plate 2). Strikes of the overlying Wasatch and Fowkes formations exhibit a similar directional change in this vicinity.

The limited lateral extent of the above structural relationships, together with the complex zone of faulting in the mouth of Springs Canyon, suggests possible salt intrusion in this locality.

Folds

Veatch (1907) described and named the Alkali Syncline which is a broad, open structure, extending from about 1 mile south of the Narrows northward for about 6 miles. The southwest extremity of Alkali Syncline is included in the area of this report. Normal fault zones border the syncline on the west and southwest (see plate 2).

Eocene sediments fill the central portion, or trough, of the syncline. Cretaceous and Paleocene formations (Gannett, Bear River, and Evanston) are exposed along the west, uplifted flank of the syncline. Strata on the syncline limb dip approximately 12 to 15 degrees east northeast.

A small anticlinal fold was mapped on the north side of the mouth of Whitney Canyon. The fold is confined to the Wasatch and Bridger (?) formations. The axial plane of the fold strikes northeast. Limbs dip approximately 3 to 5 degrees away from the axial plane. Normal faults terminate the fold on both the east and the west (see figure 12).

Veatch (1907) mapped a large anticline from the Narrows northward. The writer investigated exposures in this vicinity and found no evidence of an anticlinal structure. East dipping strata on the west limb of Alkali Syncline were interpreted by Veatch as also forming the east limb of "Narrows Anticline". West of this synclinal limb, the writer found Wasatch and Fowkes beds in a near horizontal attitude, and topographically lower than the beds comprising the synclinal limb. This evidence has led the writer to the conclusion that a normal fault separates the flat-lying beds from the synclinal limb.

Landslides

Two small slump features were mapped as Quaternary landslides. Both features occur along the trace of normal faults. Internal structures are jumbled and chaotic. One landslide was mapped about $\frac{1}{2}$ mile north of Shell Hollow, along the Shell Hollow Fault (Veatch's "Almy Fault"). The other landslide was mapped about $1\frac{1}{2}$ miles north of the mouth of Whitney Canyon. The landslides are of small areal extent. Blocks of Wasatch and Fowkes strata are involved in the slump masses.

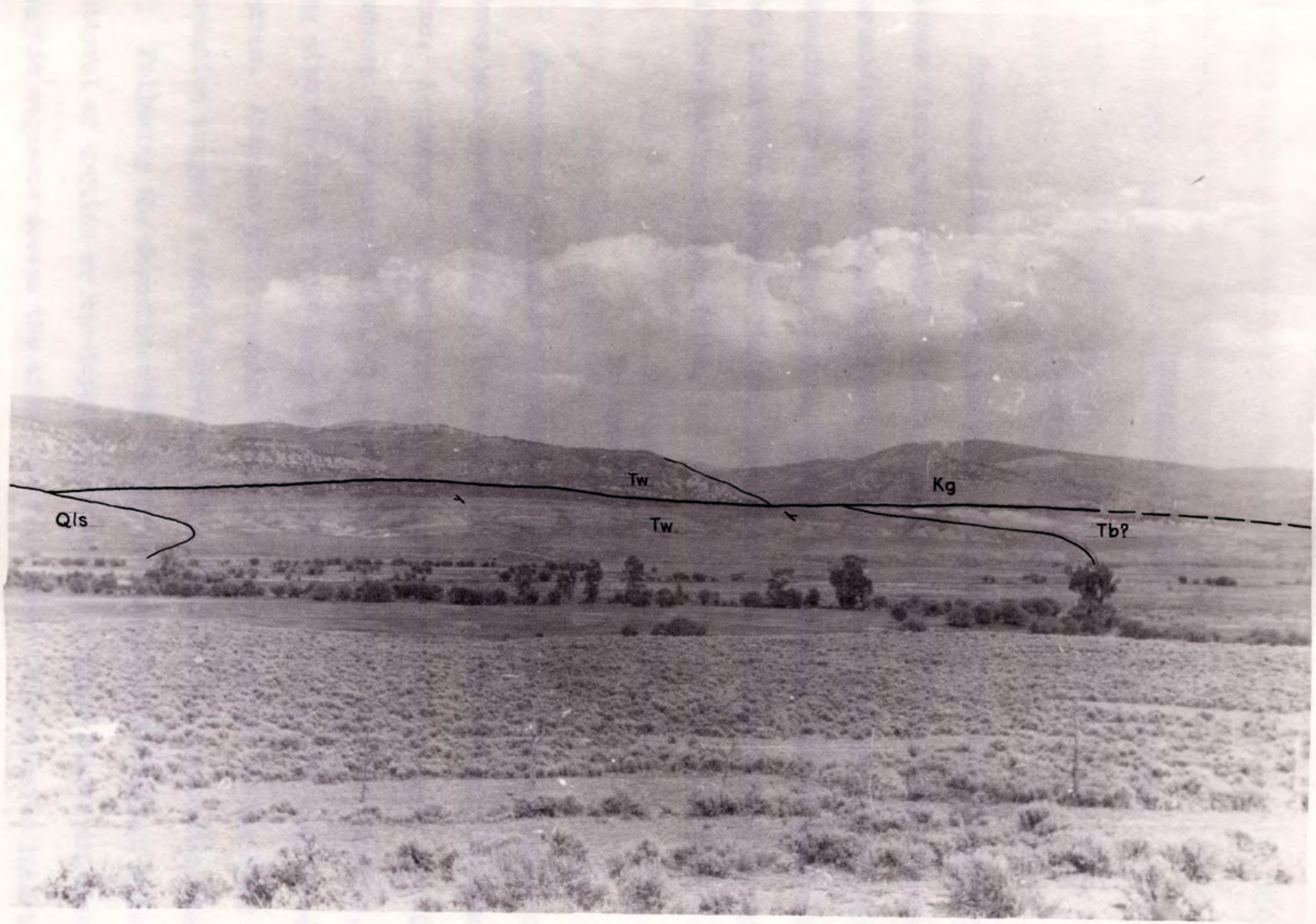

Figure 12. View eastward, just south of Alkali Syncline, showing local anticlinal fold in the Wasatch and Bridger (?) formations.

GEOLOGIC HISTORY

General Statement

Sedimentation, erosion and diastrophism from mid-Cretaceous to late Eocene time are recorded in the exposures in the area of this report. Late Laramide orogenic activities are reflected in the area by coarse clastic deposits, folds, faults, and deposition of extrusive igneous derivatives. Two thick formations of limited lateral extent, indicate local development of deep basins of deposition.

Cretaceous period

Sandstones, calcareous sandstones, and limestones of the upper Gannett group were accumulating in the area toward the close of Early Cretaceous time. Sedimentation continued without interruption into early Late Cretaceous (Cenomanian) time. The basin of deposition subsided rapidly, filling with the thick fresh-water shales and limestones of the Bear River formation. Abundant plant remains and fresh-water mollusks in the Bear River formation suggest a moist, sub-tropical climate during Cenomanian time.

Following the deposition of the thick Bear River formation, a long interval of erosion or non-deposition ensued. A major hiatus in the stratigraphic sequence covers the time span from early Cenomanian to latest

Cretaceous or earliest Tertiary time. The absence of sediments between the Bear River formation and Evanston formation is of local extent, however. Late Cretaceous unconformities are noted in surrounding areas (Burger, Nixon, Veatch, et. al.), but none of such magnitude as that found north of the town of Evanston. During the period represented by this major unconformity, thick, coarse clastics were being deposited to the west of the area, in the Coalville and Echo Canyon regions of Utah. These coarse clastics were derived from highlands produced by orogenic uplift farther west.

Two orogenic intervals have been described by Eardley (1959) from the northeastern Utah region, covering the interval of Upper Cretaceous time represented by the Evanston-Bear River unconformity in southwestern Wyoming. According to Eardley:

> "The orogeny indicated by the basal Wanship unconformity and conglomerate is Colorado in age and hence, by definition, is pre-Laramide. No name has been given it."
>
> "The Echo Canyon conglomerate is approximately equal in age to the conglomeratic section of the Price River formation of central Utah (Spieker, 1946), although the Echo Canyon may have begun to accumulate a little earlier. The orogeny has been called the Early Laramide (Eardley, 1951)."

Eardley (1959) further notes that a broad area of southwest Wyoming and northeast Utah was subjected to folding and thrusting following the deposition of Echo Canyon beds. The Willard and Absaroka thrusts are included in this phase. The deformation preceded deposition of Evanston strata, and is therefore of Montana age. It constitutes the major orogeny of the region, and is classified as the late phase of the Early Laramide Orogeny (Eardley, 1941, 1959). Uplift during this orogeny supplied the clastics of the Evanston formation.

Approximately 14,000 feet of mixed marine, brackish-water, and fresh-water sediments were accumulating to the east in central Uinta County, Wyoming (Burger, 1955), during the greater part of Late Cretaceous time. This sequence, between the base of the Aspen formation and the top of the Adaville formation, is absent in the area north of Evanston. The Evanston formation is absent in central Uinta County (Burger, 1955), but is found resting unconformably upon the Adaville north of Kemmerer, Wyoming (Tracy and Oriel, 1959).

The Frontier formation is exposed both east and west of the report area. It is approximately 2,200 feet thick in central Uinta County, Wyoming (Burger, 1955), and about 2,100 feet thick in the Coalville area of Utah (Madsen and Williams, 1959). Correlation of other Late Cretaceous formations between central Uinta County and northwestern Utah is difficult due to greatly dissimilar lithologies.

Absence of strata between the Bear River and Evanston formations, in the area north of Evanston, may be explained as follows:

a. The area stood as a highland during Late Cretaceous time, and acted as a barrier between the flood of coarse clastics to the west and the thick basin sediments to the east.

b. The area may have received thin, shelf-type deposits during some part of Late Cretaceous time. Following the deposition, in pre-Evanston formation time, uplift resulted in erosion which removed the sediments down to the Bear River formation. The area then subsided to form the basin of deposition of the Evanston formation.

c. Combination of the above conditions in which the area experienced intervals of deposition and non-deposition and erosion. Intervals of non-deposition or erosion exceeded that of any deposition, leaving no evidence of deposition having occurred.

Absence of any further evidence bearing on the history of the Upper Cretaceous in the area of this report precludes the selection of any one of the above possible concepts. Therefore, the Upper Cretaceous paleogeology of this area must remain open to question.

Tertiary period

Paleocene epoch. Deposition of the Evanston formation began in latest Cretaceous time and continued without interruption into Paleocene time. The basin of deposition was of limited areal extent and exceptional depth. The Evanston formation has been mapped from Evanston, Wyoming northward into the central area of Fossil Basin, in a narrow belt 4 to 5 miles wide.

Sandstones and conglomerates in the Evanston formation reflect intermittent phases of orogeny. The clastics become more fine grained to the east, indicating a western source. Coal and limestone deposits suggest a few intervals of quiescence resulting in swampy, lagoonal environments. Following Evanston deposition, and prior to the flood of Wasatch clastics, a period of erosion and non-deposition ensued. This hiatus spans latest Paleocene and early Eocene time. Erosion cut a surface of moderate relief, which was later buried by the Wasatch deposits. Continued uplift to the west provided a source for the thick Wasatch clastics. This late Paleocene uplift is called the Middle Laramide Orogeny (Eardley, 1941, 1959).

Eocene Epoch. Following the late Paleocene uplift to the west, the thick clastic outwash of the Wasatch formation spread over a greater part of southwest Wyoming and northwest Utah. Throughout most of the region, the Wasatch was deposited on a surface of moderate relief, up to 500 feet (Eardley, Burger, Nixon, i.e.). Relief was slight in the vicinity north of Evanston (maximum of about 30 feet).

Wasatch deposits consist primarily of conglomerate, coarse sandstones, and minor amounts of claystone and siltstone. Burger (1955) concluded these clastics are the result of torrential stream action. The Wasatch formation interfingers with the Green River formation to the east indicating oscillating shorelines and changing rates of sedimentation (Burger, 1955). The Green River beds are fresh-water lake deposits.

Broad folding followed the deposition of the Wasatch in the vicinity of the Wasatch Mountains of northern Utah (Eardley, 1941, 1959). Normal faulting accompanied the post-Wasatch folding, and probably persisted until after the deposition of the Fowkes formation. At least, the post-Fowkes faulting is believed by Eardley (1959) to be a continuation of the faulting which began during the post-Wasatch deformation.

Volcanic derivatives were deposited in middle and late Eocene time. Two thin remnants of a highly altered andesite deposit were mapped in the area north of Evanston, Wyoming, and are tentatively assigned to the Bridger formation of middle Eocene (Bridgerian) age, on the basis of lithology and stratigraphic position. This would place the first igneous extrusive activity of the area in middle Eocene time.

The Bridger (?) formation thickens eastward from approximately 350 feet in the vicinity of Evanston to about 1,500 feet near Fort Bridger, Wyoming. This suggests that the center of volcanic activity lay to the east.

Tracy and Oriel (1959) noted that strata in the central portion of Fossil Basin, tentatively referred to the Bridger formation by Veatch (1907), form an upper tongue of the Wasatch formation, merging with lower tongues along the periphery of Fossil Basin.

Volcanic activity continued into late Eocene time, during which the Fowkes formation in southwest Wyoming and the Norwood formation and Park City volcanics in northeast Utah accumulated.

Fossils and lithologies in the Norwood formation correlate closely with those of the Fowkes formation. Eardley (1959) has pointed out the possibility that the Norwood and Fowkes formations are one and the same, both being derivatives of the Park City volcanics (see page 67).

Considering the Fowkes and Norwood formations as one deposit, the writer believes two possibilities exist:

1. The Fowkes and Norwood pyroclastics were derived from the same

source as the Park City volcanics, and are of nearly the same age. The tuffs were subsequently reworked by fluvial and lacustrine processes.

2. The Park City volcanics and Fowkes-Norwood formations were derived from two volcanic centers during late Eocene time.

The writer believes the conditions outlined in 1. are most accurate and conclusive.

Eardley (1959) noted that the Fowkes exposures of southwestern Wyoming are confined to the belts of normal faulting which followed the deformation of the Wasatch strata. He states:

> "Most of the faults cut the Fowkes, but the confinement of the Fowkes volcanic outwash to the belt of faulting indicates that a main drainage way had been established before Fowkes deposition, and therefore, that deformation along the zone had occurred before Fowkes time. The deformation might well have been associated with salt intrusion, solution, and collapse, along with faulting. It seems possible, therefore, that the major faults had been established before Fowkes time, and that movement continued on them afterward."

Faults which cut the Fowkes formation cannot be accurately dated in the report area. The sedimentary record in post-Fowkes time consists only of a long period of erosion and recent deposition of alluvium and gravels along stream valleys and river benches. Few of the faults are expressed in the present topography. Study of the existing fault line escarpments gave no indication of recent movement.

GEOMORPHOLOGY

General statement

The land surface north of Evanston is in the late youth stage of the geomorphic cycle. A considerable part of the initial erosional surface remains undissected. The Bear River displays well developed meanders between Almy and the Upper Narrows, giving the appearance of maturity. Meanders are not characteristic of the river along its course above or below this locality. The writer believes the river has reached local, or temporary, grade in this vicinity, possibly due to the lowering of the valley through faulting (see page 74).

Broad, pediment-type erosion surfaces were developed over most of southwest Wyoming and adjacent Utah during late Tertiary time. Remnants of these ancient erosion surfaces form prominent geomorphic features in southern and central Uinta County (Burger, 1955; Nixon, 1955), but are not apparent north of Evanston.

Glaciation was a prominent factor in the development of geomorphic features on the north flank of the Uinta Mountains, 25 to 30 miles south of Evanston. Glacial features are found as far north of the Uintas as Hilliard Flat (10 to 12 miles southeast of Evanston), but are not found in the area north of Evanston.

Drainage patterns

Tributaries of the Bear River north of Evanston form a dendritic drainage pattern, and are of the consequent and insequent variety. Subsequent stream development is generally absent.

Landforms

Uptilted strata along the eastern side of the Bear River Valley form cuestas which dip to the east and northeast. The angle of dip increases from about ten degrees along the eastern river valley margin to nearly sixty degrees at the eastern extremity of the mapped area.

Two landslides were mapped along the east margin of the river valley. Both are found in close association with normal faults. These features are considered to be landslides from the tumbled, chaotic nature of the included blocks of Wasatch strata. The close association of landslides and faults suggests a cause-and-effect relationship, i.e., landslides resulting from oversteepening through faulting.

Terrace remnants were found in two localities: along the west side of the river valley, opposite Almy, and along the east side of the river valley from Whitney Canyon north approximately one mile (see figures 13 and 14). The terrace surfaces are presently about 125 to 150 feet above the river bed. Terrace development is confined to outcrops of Fowkes formation, although all Fowkes exposures do not exhibit terrace development. Terraces in the Almy vicinity are clearly cut on top of a very hard, resistant limestone bed in the Fowkes formation. Both the terrace surface and underlying beds in the Fowkes are horizontal. Relations between

Figure 13. View northeastward from the mouth of Whitney Canyon, showing the structural terrace slong the east side of the Bear River Valley.

Figure 14. View southwestward from the central part of the area, showing the structural terraces along the west side of the Bear River Valley.

terrace surfaces and underlying Fowkes beds, north of Whitney Canyon, are not clear. The terraces are horizontal, but the underlying Fowkes strata are so decomposed that attitudes could not be accurately determined. Strike and dip measurements were widely divergent, and are considered unreliable. The apparent dip is northeast, at a small angle (from two to five degrees).

The writer believes these terraces are of the structural type due to the following factors: 1) confinement of the terrace development to exposures of Fowkes formation; 2) limited areal extent of the terraces; and 3) lack of terrace development in other areas along the river valley underlain by soft strata.

Just north of the Heward Ranch, the Bear River abruptly departs from its northerly flow along a graben valley and turns easterly, cutting a deep ravine through the uplifted west flank of the Alkali Syncline. The river emerges from this ravine flowing west, continuing into Utah. The arcuate ravine is termed the "Narrows" (see plate 2).

Fowkes strata occupy the northern extremity of the graben valley just north of the point where the river turns east and enters the Upper Narrows. The river crosses a major normal fault both upon entering and emerging from the Narrows, and is discordant with structures in this locality.

The development of the Bear River course through the Narrows may be a result of superposition after extensive Fowkes flooding, or antecedent stream development during and after faulting, or a combination of both. The writer is unable to make a definite conclusion regarding the above.

ECONOMIC GEOLOGY

General statement

Considerable bituminous coal was produced from the Evanston formation near Almy from 1850 to the early part of the 20th Century. Coal mining in this area has now entirely ceased.

Oil occurrences in Uinta County were first reported by Clayton (1848, p. 18-24). Exploration for oil has been sporadic since that time and production has occurred in several instances, although it has been of minor economic importance.

Highway construction materials and ceramic clay deposits are mined in the vicinity of Evanston, but are of minor economic importance.

Coal

Low grade bituminous coals occur in the Evanston formation in the vicinity of Almy. Several mines were opened in this area during the latter part of the 19th Century. The town of Almy was established as a result of the coal mining activity, but has since been abandoned with the exception of a few ranches and farms. Unfavorable economic conditions, together with fires in the mines, brought about the closing of mining operations many years ago. Veatch (1907, p. 113-139) gives a thorough summary of the Almy coal industry.

Coal production throughout adjacent portions of Uinta County has been more consistent and profitable than in the Evanston area. Important producing horizons throughout the county are the Frontier, Adaville, Evanston, and Bear River formations. The Frontier formation has been the most important coal producer.

Oil

Oil springs, or seeps, were presumably known to many early settlers of southwest Wyoming. Clayton (1848) was first to record these occurrences. Sporadic drilling of the area followed, with unsuccessful results, until the year 1900. In that year the Union Pacific Railroad encountered oil in a test hole. There followed a short-lived, but intense period of oil exploration.

No commercial production of oil has been reported in southwest Wyoming, although numerous wells have been drilled up to the time of this writing (1961).

Possible oil structures are the Stove Creek structure near Hilliard, and the Sulphur Creek field southwest of Evanston (Nixon, 1955). Aspen and Bear River shales appear to be the source beds for the oil in this region (Eardley, 1959; Burger, 1955; Veatch, 1907; et. al.).

Oil exploration in Uinta County is made difficult due to the masking of underlying geologic structures by thick Wasatch beds.

Highway materials

Conglomerates in the Brown's Park and Wasatch formations are utilized as foundation material in the construction of highways. Gravel pits are situated just east of Evanston.

Ceramic clays

Clay mining operations in Christensen Hollow, about one mile east of the report area, were in the initial stages during the summer of 1960. Private individuals are conducting this enterprise, and the writer was unable to learn much about the nature of the deposit. The material is light gray to white, and is exposed in the canyon floor. The writer believes the material comes from the Fowkes formation, due to its color and occurrence. Clay is shipped by truck from Evanston to Salt Lake City, Utah, where it is utilized in the manufacture of white building brick.

Exposures of Fowkes strata on the north side of Whitney Canyon contain a high percentage of claystone, which appears to be quite bentonitic. Mining of this material could be accomplished by stripping methods, and could prove to be economically profitable.

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